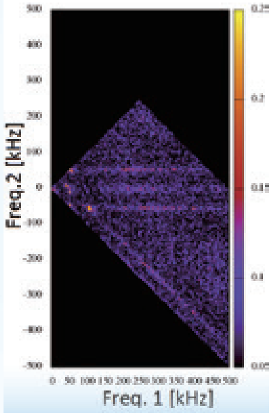
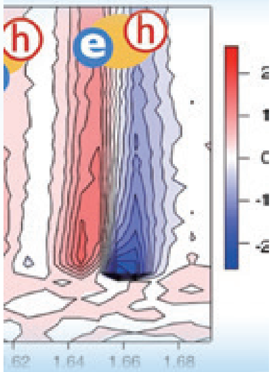
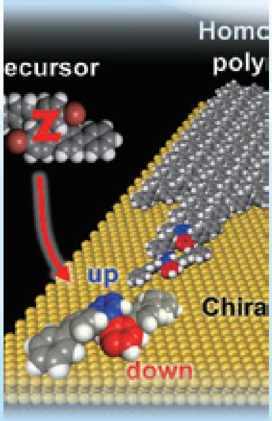




Institute of Advanced Energy

Kyoto University

2018

http://www.iae.kyoto-u.ac.jp/en

Foreword

Director

Yasuaki Kishimoto

Yasuaki Kishimoto

The various forms of energy that sustain the existence and activities of humanity and the matter generating them were created in the ingenious and subtle workings in nature, some of which seem to have been incredibly fortuitous, such as the birth of the universe—estimated to have occurred 13.8 billion years ago—and the later emergence of the sun, the earth, and life itself. Reflecting on all this, we could be requested to understand how such energy and matter have been produced in universe and how such subtle mechanisms of nature have been existed, and then to pursue the safe forms of 21-century energy that excels in terms of both “quality” and “quantity”.

The Institute of Advanced Energy was established in May 1996 for the purpose of conducting energy science by probing into the laws and basic principles of nature, as well as investigating new, next-generation forms of energy under the development of state-of-the-art technology to utilize them for practical applications. For this purpose, the institute’s 14 sections are organized as three divisions, each dedicated to one of the three basic kinds of energy processes: energy generation, energy conversion, and energy utilization. On top of this, we set up the Laboratory for Complex Energy Processes (including 3 sections). This laboratory organically integrates the 14 disciplines to enable us to tackle complex research projects and academically demanding research challenges. Already, this unique lab has produced a wealth of research findings. Furthermore, we actively pursue the internationalization of research exchanges and participate in industry–academia–government collaboration to channel the fruits of our research back into society for the public good. The institute is also in charge of the Graduate School of Energy Science’s Cooperating Chair, which conducts student education and trains researchers in a leading-edge research environment.

In 2011, the institute began operating as a “Joint Usage / Research Center” under the name Zero-Emission Energy System, applying the energy ideals of the institute to the challenge of “zero emissions”. Under this initiative, the institute employs its broad variety of resources to promote collaboration/cooperation and the formation of communities across multiple academic disciplines. As it happens, the research center was launched around the time of the Great East Japan Earthquake, an event that spurred Japan to look more deeply at the question of energy, and ever since the center has grown apace with national efforts to recover from the disaster. We would like to express our sincere gratitude to everyone for their support and cooperation thus far in the efforts of this unique research center.

At this point of the 21st century, scientific research is at an important crossroads, both in Japan and internationally, because the integration of different disciplines is now indispensable to achieving significant development, just as the cross-stitching of different two vertical and horizontal threads is essential to creating a beautifully patterned fabric. The integration of different disciplines is no easy matter, however. It cannot be achieved just by the limited staff of one research institute. New knowledge and new people must be constantly brought in from the outside to stimulate spirited debate and bold initiatives. Then through such efforts, new ideas are developed and applied in the real world, to explore new value, which then returns to the institute. Integration can be truly achieved only through a “circular” process such as this. Internationally too, as an energy research adopts assorted new ideas and technological innovations in the pursuit of scientific advancement, what we select and what we aim at are the important key issue. Keeping this firmly in mind, everyone at the institute works together and contributes actively to discovering insights, without limiting themselves to existing methods and concepts. Through exhaustive debate within a broad context that encompasses the whole of society, the institute is constructing a foundation for a new style of energy science and technology suited to 21st-century needs. As we make this effort, we look forward to your support and cooperation.

CONTENTS

Mission and Goal

The Institute of Advanced Energy (IAE) was established to promote researches to sophisticate the generation, conversion, and utilization of energy. Our goals are

(a) to conduct pioneering research on advanced energy science and technology,

(b) to propose solutions to energy and environmental issues associated with rapid global population expansion,

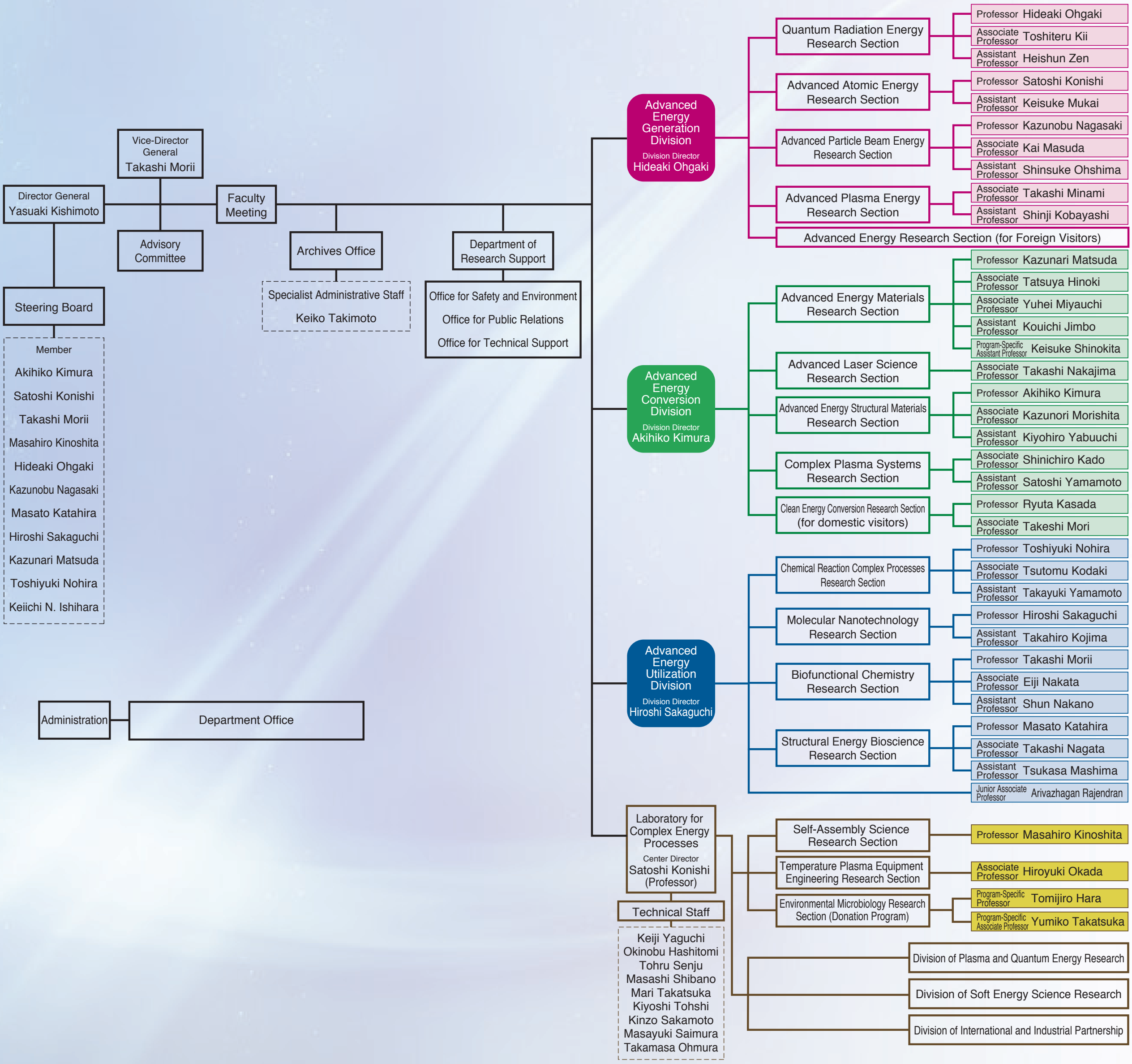
(c) to contribute to the sustainable progress of humankind.

We perform comprehensive approach towards development of next-generation energy systems, which have the potential to replace existing energy systems, with two viewpoints, Quality (harmonization with the environment) and Quantity (social infrastructure). In order to secure sustainable energy resources or systems, our research activities emphasize improving the performance of energy systems, developing new energy resources, and realizing systems for effective use of energy resources, which can be named as Zero-Emission Energy System. Moreover, through these endeavors, we aim to foster scientists and engineers who possess advanced knowledge and skills in energy science and technology.

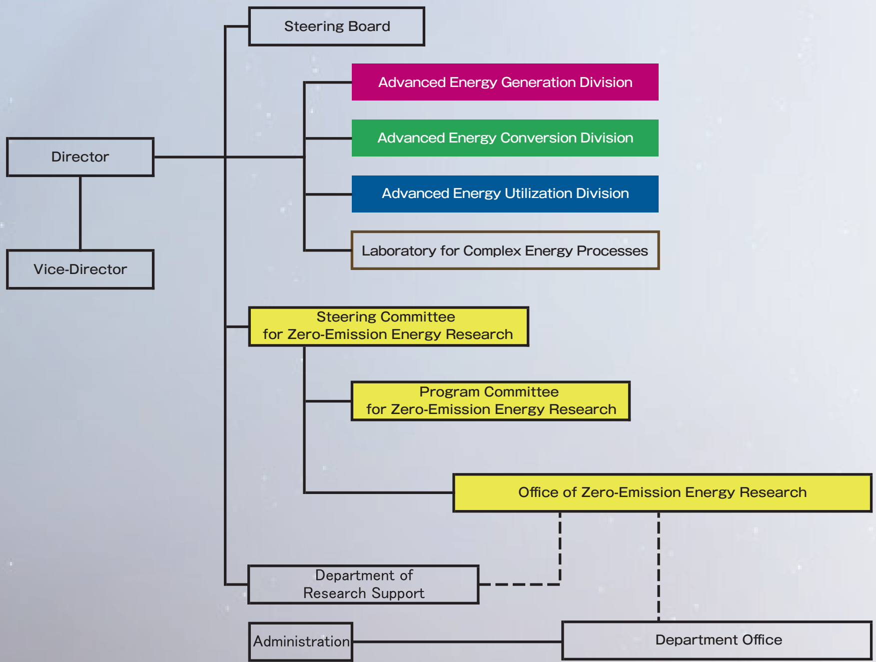
To meet our objectives, we strive to further develop the research field of Advanced Energy (or Zero-Emission Energy) by building an innovative energy system that has high social receptivity, as well as by developing a system capable of incorporating various sources of energy. Human and research resources at IAE, which are from diverse academic backgrounds, will be strengthened and organically coordinated among different research fields, thereby promoting interdisciplinary and fused research. IAE serves as a hub for advanced energy research in Japan and around the globe.

These activities will further pioneer and develop advanced energy research to bridge us to the next generation and contribute to the growth of society.

Organization Chart



Organization for Zero-Emission Energy Research Project



History


Engineering Research Institute


10th Anniversary of Kyoto University Engineering Research Institute


Institute of Atomic Energy

Institute of Advanced Energy Inaugurated

- 1914 ◀ Research Center in Faculty of Engineering
- 1941 ◀ Engineering Research Institute with 5 divisions
- 1959 ▶ Heliotron A
- 1960 ▶ Heliotron B
- 1965 ▶ Heliotron C
- 1966 ◀ Plasma Physics Laboratory (Faculty of Engineering)
- 1968 ◀ Moved from the Main Campus to Uji Campus
- 1969 ▶ Laboratory for Nuclear Reactor Safety Analysis
- 1970 ▶ Heliotron D
- 1971 ◀ Renamed to Institute of Atomic Energy with 8 Research divisions
- 1972
- 1975

Plasma Physics Laboratory ◀

Start of "Joint Usage/Research Program on Zero-Emission Energy" (2016-2021) ◀ **2016**

Start of "Joint Usage/Research Program on Zero-Emission Energy" (2011-2015) ◀ **2011**

2010 ▶ NMR

Laboratory for Complex Energy Processes reorganized ◀ **2006**

National University Corporation Kyoto University ◀ **2004** ▶ Laboratory for Photon and Charged Particle Research, DuET, KU-FEL
▶ Laboratory for Energy Nano-Science Research

1999 ▶ Heliotron J

Institute of Advanced Energy ◀
Laboratory for Complex Energy Processes ◀ **1996**

1983 ▶ Plasma Energy Direct Energy Conversion Laboratory

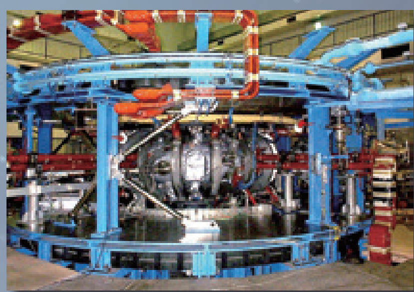
1981 ▶ High Temperature Liquid Sodium Heat Transfer Experimental Facility

1980 ▶ Heliotron E

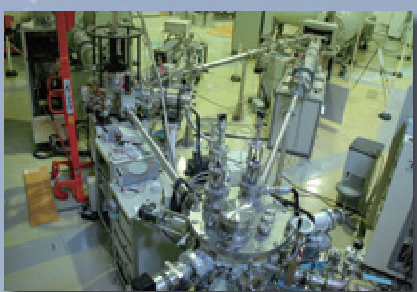
1976

▶ Heliotron DM

▶ Magneto Plasma Research Laboratory

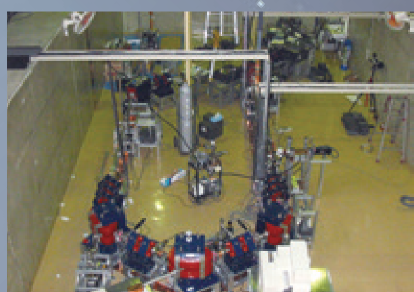


Heliotron J



DuET

NMR



KU-FEL

Division Introduction

Advanced Energy Generation Division

We promote the development of socio-friendly and fundamental "zero-emission energy system" that should be an inevitable issue sustainable future of humankind, and innovative energy sources with particular function including their application technology.

Advanced Energy Conversion Division

Aiming at the efficient conversion of energy functions and the generation of new energy functions, this division studies fundamental energy-material interaction and its applications, efficient energy-conversion processes, and the development of functional energy materials.

Advanced Energy Utilization Division

The aim of division is the establishment of 'Emergent Materials Science' having a similar concept seen in energy-related processes in nature, efficiently converting 'soft energy' into 'electricity' and 'valuable chemicals' without huge consumption. The research projects ongoing cover the researches of energy-related materials sciences, chemistry and biosciences for the development of new technologies for renewable energy conversion and utilization.

Laboratory for Complex Energy Processes

This Laboratory is a core research center for strategic and multidisciplinary collaboration studies in IAE, offering cooperative project activities in the field of the advanced energy. The Center has three divisions : (1) "Division of Plasma and Quantum Energy Research", for fusion and related advanced energy studies, (2) "Division of Soft Energy Science Research", that promotes innovative functional materials based on nanotechnology and biotechnology, and (3) "Division of International and Industrial Partnership" that promotes and enhances activities and relationship with foreign and domestic research partners including industry and private sector. This center privides a platform for the collaborative and ambitious research activities of the IAE in the field of advanced energy studies.

Interactions among Divisions

The Institute of Advanced Energy has three divisions including "Advanced Energy Generation Division", "Advanced Energy Conversion Division", and "Advanced Energy Utilization Division". Each division conducts distinct research from their own viewpoints as described in next section. In addition to these researches, interdisciplinary research is also necessary to develop advanced energy indispensable for the sustainable development of humankind and to realize next generation energy systems, especially our current targeted energy, "Zero-Emission Energy".

Towards this goal, the Laboratory for Complex Energy Processes has been promoting interdisciplinary collaborative research projects among three divisions since the establishment of the laboratory. Such collaborations through the projects now focused on two research fields of "Plasma & Quantum Energy" and "Soft Energy". This multilayered structure of our research activities has enhanced the comprehensive capabilities of the institute, thereby creating a unique research institute that differs from the other energy related institutes.

Quantum Radiation Energy Research Section

Research on Generation and Application of New Quantum Radiations, i.e. Compact MIR Free Electron Laser, Table-Top THz coherent radiation, and Laser-Compton Gamma-ray. International collaboration research on efficient utilization of low rank coal and biomass and renewable implementation in ASEAN.

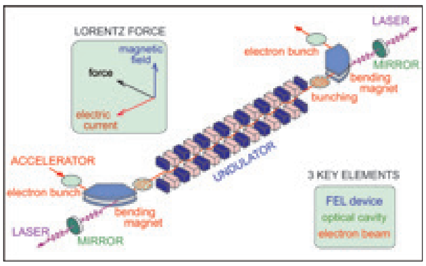
Professor
Hideaki Ohgaki

Associate Professor
Toshiteru Kii

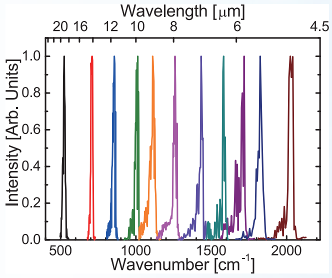
Assistant Professor
Heishun Zen

Generation and Application of New Quantum Radiation

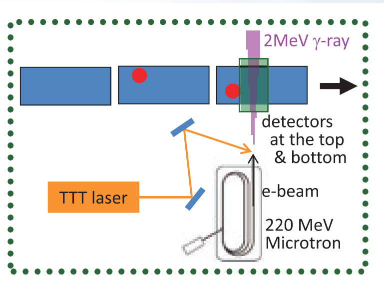
Generation and application of new quantum radiations from relativistic electron beams have been studied. Free electron laser, which is generated by a high brightness electron beam from accelerator, is considered as one of new generation radiation sources. FEL is tunable laser with a high power. We have developed a thermionic cathode RF gun with our original RF control system to generate mid-infrared FEL with compact accelerator system. In 2008 we succeeded in FEL power saturation at 13.6 μm in wavelength and now the FEL can provide the intense laser light in the wavelength region from 3.6 to 25 μm. As application researches, we promote the mode-selective phonon excitation experiment to study on wide-gap semiconductors in cooperation with in-house users as well as outside users. Generation and application of Laser-Compton Gamma-ray beam has been studied for the nuclear safeguard and nuclear security. A short period undulator consists of bulk high Tc superconducting magnet and table- top THz coherent radiation have been studied as well.



Principle of FEL
Generation of Free Electron Laser (FEL) is based on the micro-bunching phenomenon driven by a high brightness electron beam which interacts with electro-magnetic field.



Wavelength Tunability of KU-FEL
This graph shows the wavelength tenability of KU-FEL. We can freely change the FEL wavelength from 3.6 to 25 μm by changing the electron beam energy from 36 to 20 MeV. The spectral width of the FEL is around 1 percent in FWHM.

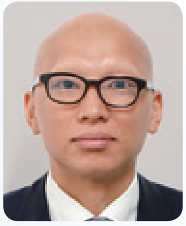


Conceptual drawing of the assay system for hidden material by using Laser-Compton backscattering gamma-rays
Quasi-monochromatic gamma-ray beam generated by collision between a high energy electron beam and a high power laser can be used for detection of hidden dangerous material.

Advanced Atomic Energy Research Section

We design and develop the zero-emission energy system powered by fusion, from its generation to utilization, and analyze it from environment, socioeconomics, and sustainability aspects.

Professor
Satoshi Konishi



Assistant Professor
Keisuke Mukai

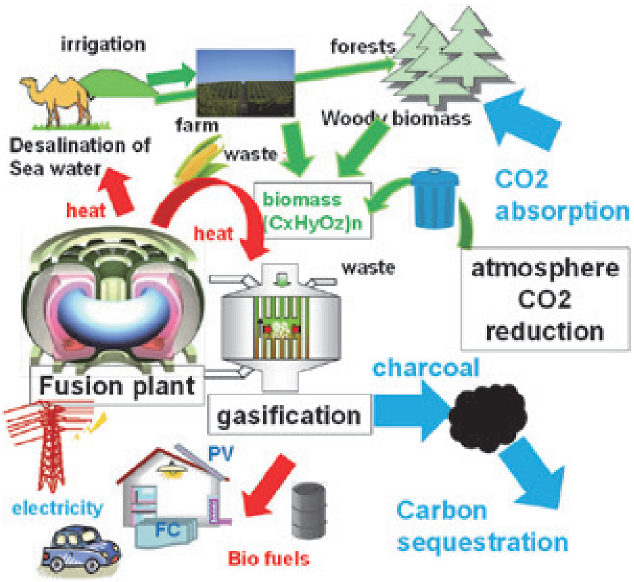
Design, Development and Assessment of Fusion Energy Systems

Zero-emission energy system that has little constraints of resource and environment is expected to provide ultimate solution for sustainable development of human in the global scale.

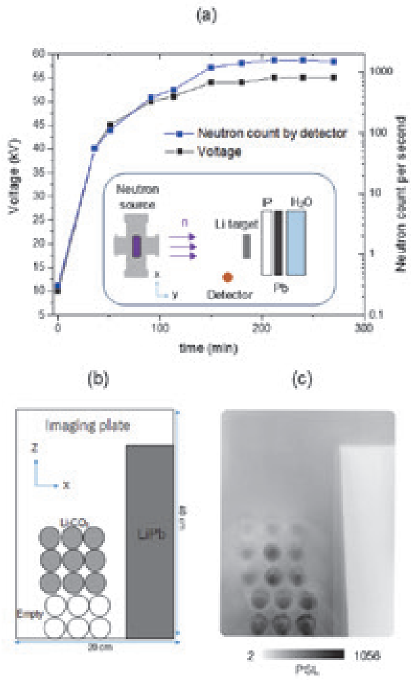
We study the fusion system design and development, as well as the integrated evaluation from social and environmental aspects. Development of new fusion device to generate neutron beam, conversion of fusion energy, and its application for the production of clean fuels are performed. Fusion is investigated from its generation to the application and adaptation to the future society. We are one of the leading research team of fusion technology, and regarded as a key station of international collaboration. Study of "Sustainability" on energy and environment is also our major topic.

A new compact neutron source and fusion blanket neutronics study

Fusion reactor requires blanket that utilizes neutron to produce fuels. Experimental system for fusion neutron behavior in the simulated assembly with an integrated material system is established as the 1st attempt in the world. The innovative system is composed with a neutron source developed by our laboratory, blanket simulating assembly, and spacial distribution of neutron is measured with Imaging Plates (IP).



Concept of Fusion-Biomass Hybrid system



Fusion Blanket experiment with neutron source, simulating assembly and imaging plates.
(a) assembly and neutron generation, (b) Li target and Imaging Plate, (c) obtained neutron image.

Advanced Particle Beam Energy Research Section

High-power microwave system, compact neutron/proton sources driven by fusion plasmas, plasma diagnostics, highly brilliant relativistic electron beam are being developed by controlling charged particles and electromagnetic field.

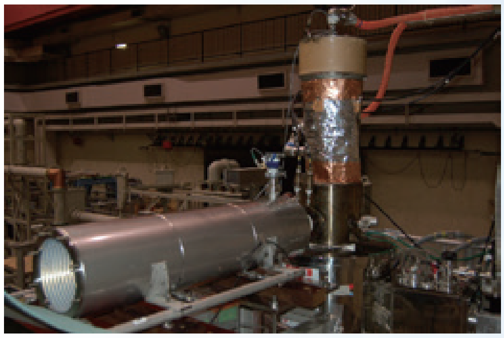
Professor
Kazunobu Nagasaki

Associate Professor
Kai Masuda

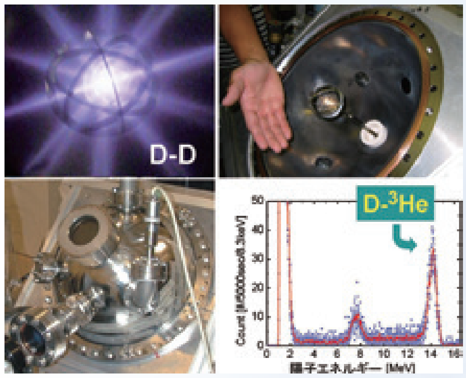
Assistant Professor
Shinsuke Ohshima

Development of Advanced Energy by electromagnetic waves and particle beams

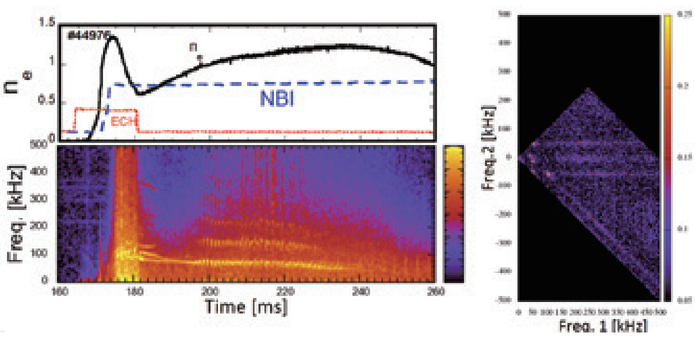
Advanced and innovative control methods for the collective behavior of charged particles are being developed in this research section to bring about enormous contributions to the human beings. Emphasized are particularly studies of nonlinear interactions between charged particles and electromagnetic fields. Production, heating, current drive and MHD suppression of fusion plasmas by electron cyclotron resonance are studied by using high-power microwave sources such as magnetrons and gyrotrons. Application of microwaves is also targeted for the development of heating and current drive systems. Clarification and understanding of physical mechanism of fluctuations existing inside the plasma is also a key issue to achieve high performance plasma because a variety of instabilities can act to transport plasma and determine the plasma confinement. Hence, advanced diagnostic tools with higher spatio-temporal resolutions such as microwave diagnostics and multichannel Langmuir probes and novel technique of fluctuation data analysis are developed and approached. Also studied are production and application of energetic particles: Production of highly brilliant relativistic electron beams are studied for the development of advanced light sources such as free electron lasers. Compact neutron/proton sources based on Inertial Electrostatic Confinement fusion are being developed for versatile applications such as PET isotope production and detection of illicit materials. Studies of advanced D-^{3}He fuel fusion are also being pursued by the use of the compact fusion device.



High-power microwave source "Gyrotron"
A gyrotron produces a Gaussian-shaped microwave beam of 70GHz 500kW power, which is used for production, heating and current drive of fusion plasmas.



Neutron / Proton Sources based on Inertial Electrostatic Confinement Fusion
Ions focused within the transparent gridded cathode undergo fusion reactions that produce energetic neutrons. Protons produced with a moderate applied voltage of tens kV gain a huge energy of 14.7 MeV via D-^{3}He fusion reactions.



Measurement and spectrum analysis of fluctuations in high temperature plasma
Various fluctuations appear in plasma and cause transport. Measurement and analysis of those fluctuations in the frequency range from kHz to MHz are important issues to understand properties of plasma transport.

Advanced Plasma Energy Research Section

Our research is aiming at developing advanced plasma control technology for plasma energy application and investigating high temperature plasma physics

Associate Professor

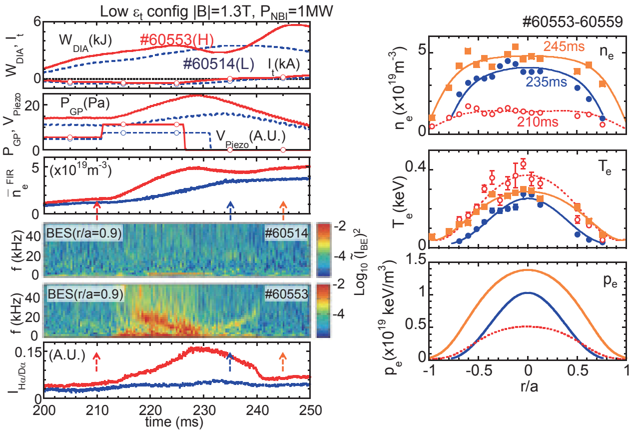
Takashi Minami

Assistant Professor

Shinji Kobayashi

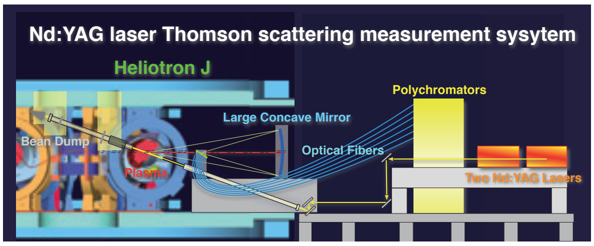
Generation of high performance plasmas by development of plasma heating, diagnostic and control technologies for plasma energy application

Our research interests focus on the physics and engineering of the high temperature plasmas for the development of the fusion energy reactor and new windows of the high temperature plasma application. Understanding and control of the heat, particle and momentum transport in plasmas are indispensable to obtain the high performance plasmas. For this sake, optimization of magnetic field configuration, development in the plasma heating and the particle fueling/pumping technologies and control of the boundary plasma conditions are the important key issues to solve the problems. The neutral beam injection based on the high power hydrogen ion sources has been utilized not only for the plasma heating, but also for the active actuator of the momentum and plasma current, which has enabled us to control the plasma transport to a preferable plasma confinement condition. As well as the development in the plasma heating technology, new fueling schemes are developed to extend the operational region toward high density plasma condition. In such the case, control of the boundary plasma is one of the important subjects not only to obtain the high performance plasmas but also to realize the optimized plasma-material interactions. In order to understand the heat, momentum and particle transport, we are developing plasma diagnostic systems such as an Nd:YAG laser Thomson scattering, a charge-exchange recombination spectroscopy, a beam emission spectroscopy and so on. These studies provide us important information of the spatiotemporal structure of the density, temperature and flow velocity of the high temperature plasmas and these fluctuation components. Recently, we have observed that the optimization of the heating and fueling schemes and the boundary plasma condition has been able to produce the high performance plasmas with the formation of the transport barrier. We are now clarifying the physical mechanism of the transport barrier formation and its relation to the turbulent fluctuations.

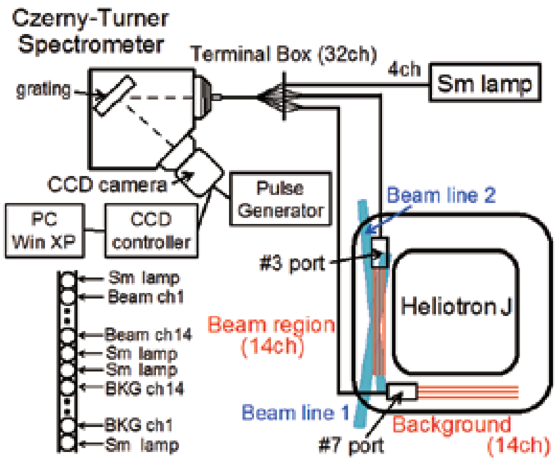


Expansion of plasma operation range by advanced fueling method

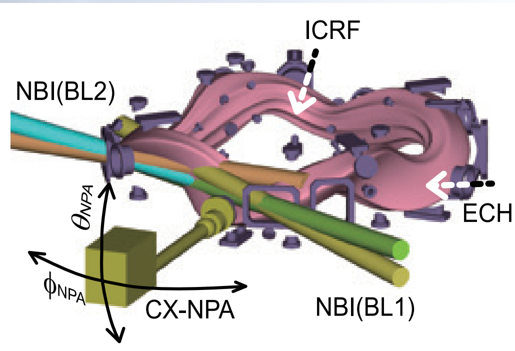
A short-pulsed high intensity gas puffing (HIGP) is successfully applied to NBI plasma in Heliotron J, resulting formation of high density H-mode plasmas with steep density gradient at peripheral region.



Schematic view of Nd:YAG laser Thomson scattering system for Heliotron J



Schematic illustration of charge-exchange recombination spectroscopy for ion temperature and flow velocity measurements



Neutral beam injection system for Heliotron J

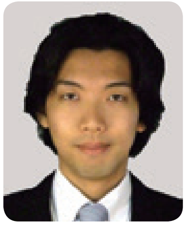
Neutral beam injection system consists of two tangential neutral beam lines (BL1 and BL2). Each beam line has maximum applied voltage of 30keV and maximum injection power of 0.7MW, respectively.

Advanced Energy Materials Research Section

We are investigating the scientific principle and applications of new nano-materials including advanced energy materials, and exploring the physical properties and functionalities of these materials based on nano-science.

Professor
Kazunari Matsuda

Associate Professor
Tatsuya Hinoki



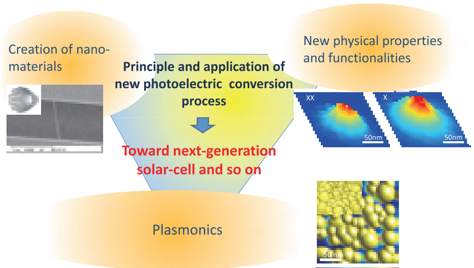
Associate Professor
Yuhei Miyauchi

Assistant Professor
Kouichi Jimbo

Program-Specific Assistant Professor
Keisuke Shinokita

1) Manifestation of Optical Functionalities and Highly Efficient Photoelectric Conversion Based on Nano-science

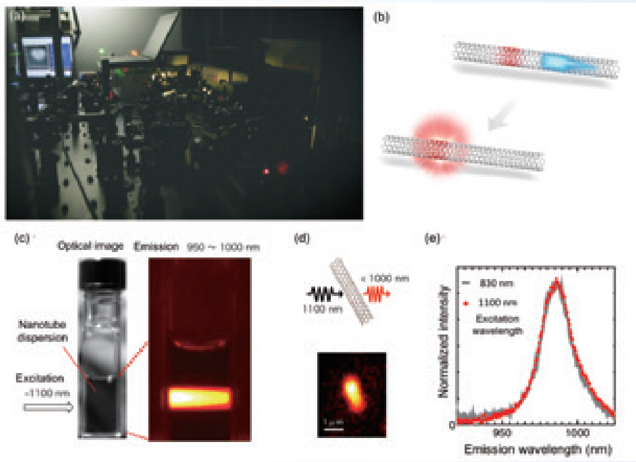
Recently, the highly efficient photoelectric conversion using sunlight is required toward the realization of sustainable society. It is required the creation of nano-materials including artificial complex nano-materials with potential applications and the understanding of physical properties. We are investigating the fundamentally quantum physical processes of the nano- material systems (carbon nanotube, graphene, semiconductor, metal nanoparticles and these complex nano-materials) using advanced laser spectroscopy. Furthermore, we are investigating the scientific principle and applications of highly efficient photoelectric conversion processes toward the next-generation solar cells.



Our Scheme toward Highly Efficient Photoelectric Conversion Process for Next Generation Solar Cells
The scientific principle and applications of highly efficient photoelectric conversion processes are studied based on nano-science. Especially, we are investigating the creation of new nano-material systems, understanding of physical properties, and manifestation of optical functionalities using plasmonics techniques.

2) Photophysics and Applications of Nanomaterials

Our research focuses on photophysical properties and applications of nanomaterials including carbon nanotubes, graphene, and atomically thin semiconductors in which distinct quantum effects dominate their physical properties. We make use of advanced optical spectroscopic techniques to clarify the physical properties of nanomaterials for developing novel energy-efficient information processing, bioimaging, and photon energy conversion technologies.

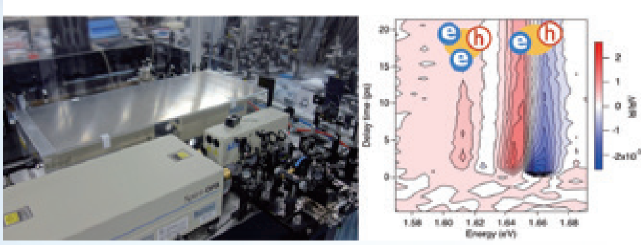


Images of optical experiment
(a), schematic of exciton dynamics in carbon nanotube with an artificially-introduced localized state (b), up-conversion luminescence image of an ensemble carbon nanotube sample (c), wavelengths of excitation and emission (d, upper), micro-photoluminescence image of an individual carbon nanotube (d, lower), comparison of the Stokes and up-conversion luminescence spectra from an individual nanotube (e).

3) Ultrafast phenomena in atomically thin-layered materials

Atomically thin-layered material including graphene comprising from monolayer carbon atoms has attracted much interest for both fundamental research and practical application because of exotic quantum states. We have investigated two dimensional transition metal dichalcogenides (MX_2; M = Mo, W, X = S, Se, Te) as the layered material with coupled spin and valley indices of charge carriers (valley-pseudospin) mainly by ultrafast spectroscopy based on femtosecond laser: Generation and relaxation dynamics of electron-hole pairs, neutral excitons and charged exciton, was revealed and control of optical properties by field effect transistor (FET) device fabrication was achieved. Now the ultrafast spectroscopic technique with device fabrication is engaged in ultrafast control of valley-pseudospin phenomena in the two dimensional transition metal dichalcogenides.

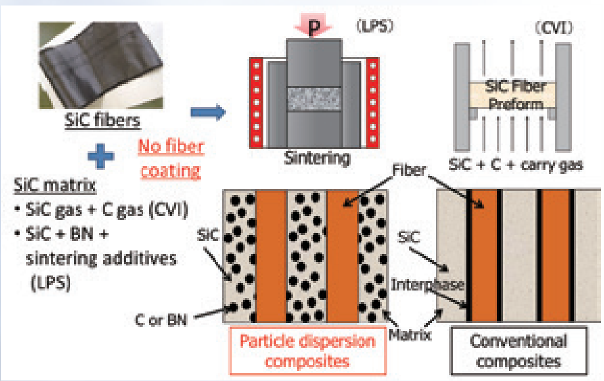
Advanced Energy Materials Research Section



A setup of ultrafast transient reflection spectroscopy based on femtosecond laser (left) and ultrafast carrier dynamics in two-dimensional transition metal dichalcogenides (right)
The ultrafast spectroscopy system based on femtosecond laser with high-repetition rate can measure time-resolved optical properties including transient reflection with femtosecond time resolution and high signal-to-noise ratio. Right figure shows ultrafast optical response of two-dimensional transition metal dichalcogenides $MoSe_2$ measured with the ultrafast spectroscopy system. It allows us to reveal physical mechanism underlying ultrafast dynamics including generation and relaxation process of the electron-hole pair, neutral exciton and charged exciton.

4) R&D of ceramic material for advanced energy application

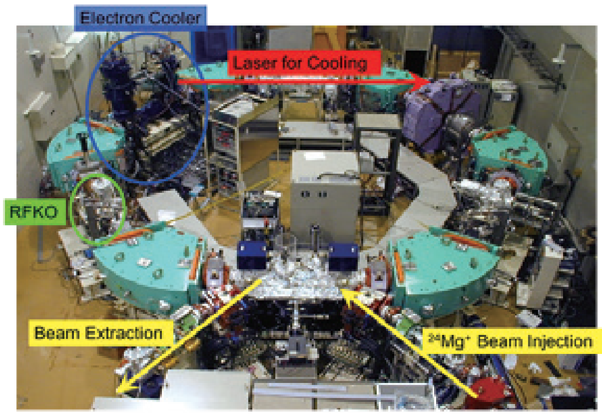
The research activity puts emphases on R&D of the advanced ceramic materials like SiC/SiC composites for nuclear advanced fission, fusion and aerospace application utilizing nano-technique. The R&D include development of novel materials, applications and environmental effects from basic science through engineering. Many collaborative researches are ongoing with domestic and international institutions in US, Italy and OECD.



Development of Particle Dispersion SiC Composites
Interphase between fiber and matrix is the weakest link for conventional SiC composites. Novel SiC composites with particle dispersion SiC matrix was developed without the interphase. The SiC composites have excellent oxidation and corrosion resistance.

5) Transverse Laser Cooling of a Magnesium Ion Beam by Synchro-Betatron Resonance

As collaboration research with Advanced Research Center for Beam Science, Institute for Chemical Research, Kyoto University, K. Jimbo engages in a laser cooling experiment of a magnesium ion ($^{24}Mg^{+}$) beam at Small Laser-equipped Storage Ring (S-LSR). As shown in the picture, the wavelength variable UV laser (280 nm) is guided into a straight section of S-LSR and co-propagates with ions so that they constitute $3s^2S_{1/2}\rightarrow 3p^2P_{3/2}$ absorption-emission cycle for laser cooling. Cooling in the longitudinal direction has already been achieved for both coasting and bunched ion beams. Now we try to cool ion beams in the transverse direction by the synchro-betatron resonant coupling.



Small Laser-equipped Storage Ring (S-LSR)
S-LSR located at Advanced Research Center for Beam Science, Institute for Chemical Research, Kyoto University has 6-fold symmetry with circumference 22 m.

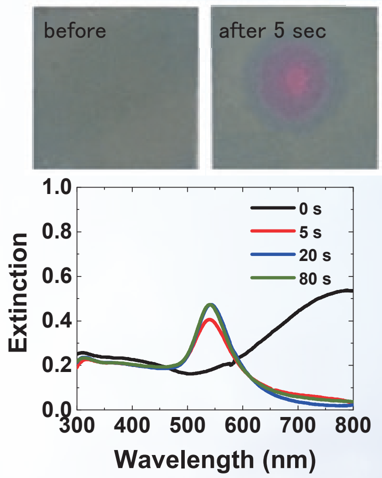
Advanced Laser Science Research Section

The use of lasers enables us to provide energy to the target materials and monitor their real-time change without any physical contact. We fully utilize such properties of lasers to synthesize nanomaterials and carry out the real-time monitoring of their dynamics.

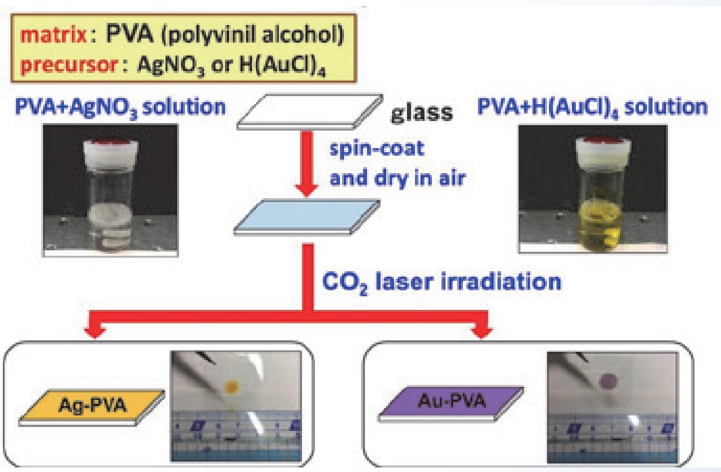
Associate Professor
Takashi Nakajima

In-situ synthesis and real-time analysis of nanomaterials using lasers

Thin films are widely used in many different fields. Typical strategies to modify the film properties are to introduce a multilayer structure or nanoparticles in the film matrix. Although precisely designed multilayer films already possess nice properties they would be better if nanostructures are introduced. As for the introduction of nanoparticles into the film matrix it is known that the direct dispersion of nanoparticles into the film matrix is not trivial, since aggregation easily takes place. One way to solve this problem is to do the in-situ synthesis of nanoparticles in the film matrix. Both of these, i.e., nanostructuring of the (multilayered) film and in-situ synthesis of nanocomposite films, can be rapidly and easily realized if we use lasers, and our research focuses on developing laser-based new schemes for the rapid nanostructuring/in-situ synthesis of nanomaterials and the real-time monitoring of the associated dynamics.



Formation of nanostructure in Au films
The color of Au films changes to violet after the laser irradiation (top figure), and accordingly the optical spectra also change (bottom figure).



In-situ synthesis of polymer-metal nanocomposite film
By irradiating a CO_2 laser at 1 W for 10 sec the polymer film with a precursor of nanoparticles becomes nanocomposite films.

Advanced Energy Structural Materials Research Section

Innovative structural materials R&D with focusing on nanomeso structural control, and basic research for understanding materials performance and behavior

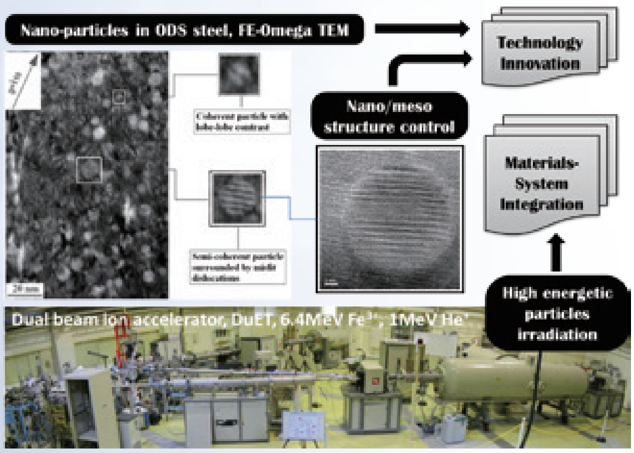
Professor
Akihiko Kimura

Associate Professor
Kazunori Morishita

Assistant Professor
Kiyohiro Yabuuchi

Fundamental Studies of Energy-Materials Science and Technology

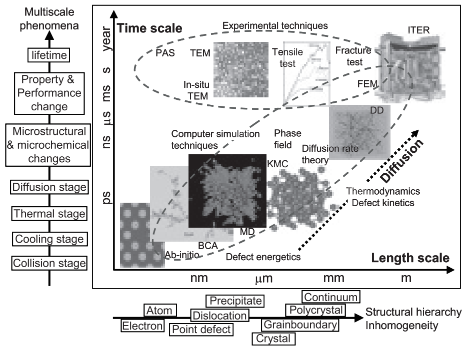
Innovative structural materials R&D is essential towards future advanced energy plants of high thermal efficiency. Nano- technology to disperse very fine (3nm) oxide particles (Y_2O_3) into steels in high density improved the strength at elevated temperatures remarkably together with bearing high corrosion resistance and irradiation tolerance. In order to make clear the mechanism of high performance, nano-scaled micro-analysis have been done using FE-TEM, FESEM, FE-AES and FE-EPMA to investigate the mechanism of material high-performance by nano-scaled oxide particles. Fundamental studies on ion-irradiation damage mechanism have been done to understand materials behavior under high-energy particles irradiation environment.



Materials nano-technology and dual ion-beam accelerator (DuET)
An example of high-resolution TEM microstructure of oxide particles in an ODS steel. The oxide particles, which consist of Y and Al, drastically improve material performance by controlling their size, number density and interfacial structure. DuET is a dual ion-beam accelerator.

Multiscale Modeling of Irradiation Processes of Fusion Materials

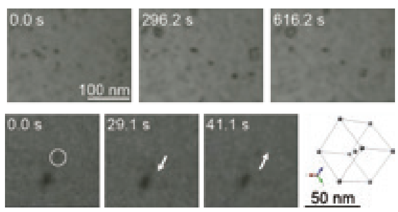
Many international programs are being underway for developing nuclear fusion reactors , which are one of the promising earth-friendly candidates for future energy sources. Material's issues are of critical importance, because reactors' integrity is basically determined by the component materials that suffer from severe irradiations. For developing irradiation-resistant materials, the database on materials' behavior during irradiation is required. However, they should reluctantly be obtained using the alternative, existing irradiation facilities such as fission reactors and ion accelerators, because of no actual fusion reactors at present. To overcome the difficulties caused by the difference between the two environments, a methodology to predict material's behavior in the actual environment using the existing materials' data is required. Our efforts have been made to establish the methodology. Molecular dynamics, kinetic Monte-Carlo, ab-initio calculations, and rate-theory equations are powerful tools to understand radiation damage processes, which occur at a wide variety of time and length scales.



Multiscale radiation damage process
Radiation damage processes show different behavior depending on timeand length-scales that you are observing. To understand these multiscale phenomena, various investigation methods using computer simulations and experiments should complementarily be employed.

Lattice Defects Behavior in Metal

Metals have crystal structures, but lots of lattice defects exist in them. The properties of metals are directly related to the lattice defects and their behavior. So, understanding of lattice defects are fundamental science of materials science. For effective investigation of lattice defects behavior, we introduce lots of lattice defects into materials with an ion accelerator, DuET, and observe their behavior. We study with both atomic scale observation using various electron microscopes and computational approaches such as DFT and MD.



One dimensional motion of lattice defects in iron
The effects of alloying elements on the behavior of defect structures have been investigated. It was revealed that Mn strongly suppressed the one dimensional motion of lattice defects.

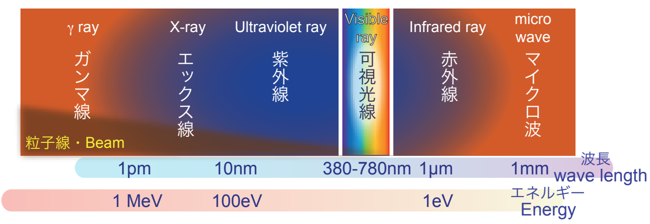
Complex Plasma Systems Research Section

Nonlinear and synergetic physics of high-temperature plasma is investigated experimentally and theoretically with special regard to the magnetic confinement improvement of fusion plasma, which would also contribute to the complex plasma systems research.

Associate Professor
Shinichiro Kado

Assistant Professor
Satoshi Yamamoto

Controlled thermonuclear fusion energy is regarded as one of the promising future base load power plants from the viewpoints of resource abundance, less environmental load and nuclear proliferation resistance. Its realization relies on the investigation of high-temperature, high-density magnetized plasma confinement. The research of plasma — the fourth state of matter — includes its feature of collective particles of electrons and ions in motion and its feature of magneto-fluid. Energy distribution of the particles or the orbit in the magnetic field will be a key issue in the former case, while the treatment of instability and turbulence will be a key in the latter case. In our laboratory, we are investigating such a complex plasma behavior in Heliotron J, a helical plasma confinement device, by means of various kinds of diagnostics or simulations. For the purpose of achieving better plasma particle and energy confinements, "plasma control schemes", such as magnetic configurations, heating conditions and fueling scenarios, are being investigated.

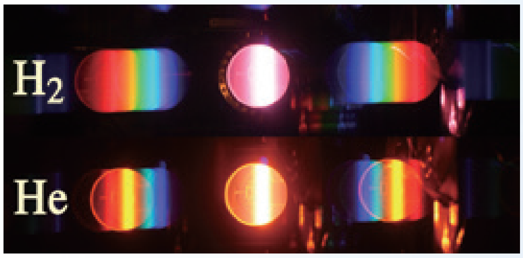


Emission of wide-range electromagnetic wave from plasmas

Light, or electromagnetic wave, plays various roles in the plasma research, such as in heating, controlling and diagnosing plasmas.

Probing What Is Real in Plasma Using Optical Emission

Optical emission from plasmas includes plenty of information such as density, temperature, ionic species and their fluctuations. "Know the enemy (plasma) and know yourself (measurement methods and data), then you can fight the hundred battles without fear" --- the real plasma properties that have never been known to anyone will be in our hands.

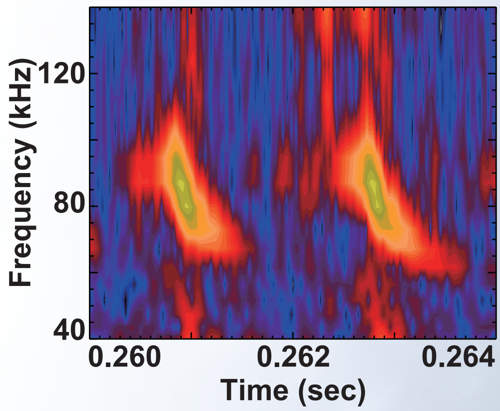


Spectral images of plasma that varies for each element and its ionization state

Plasma emits various line spectra as can be seen through a simple grating film. One can draw huge amount of information from the high-grade spectrographs.

Performance improvement of magnetically confined plasmas by control and suppression of fluctuations

We are aiming at having good plasma confinement by means of the control and suppression of several kinds of unfavorable fluctuation in high-temperature plasmas, based on experimental and numerical studies. In particular, I am interested in the resonant wave-particle interaction, which leads to destabilization of fluctuations that degrade the fusion plasma confinement and is commonly observed in nature.



Nonlinear resonant wave-particle interaction in a fusion plasma

Shear Alfvén wave, which is one of the magnetohydrodynamics (MHD) waves in a plasma, would be resonantly excited by the energetic ion whose velocity is similar to the phase velocity of shear Alfvén wave. The frequency chirping of the observed fluctuation is caused by nonlinear resonant wave (MHD waves)-particle (energetic ions) interaction.

Chemical Reaction Complex Processes Research Section

We are studying materials and systems to realize renewable energies like photovoltaics and bioenergy as the major primary energy source for human beings. We are conducting innovative researches that cover the phases from basic research to applications mainly based on electrochemistry and biochemistry.

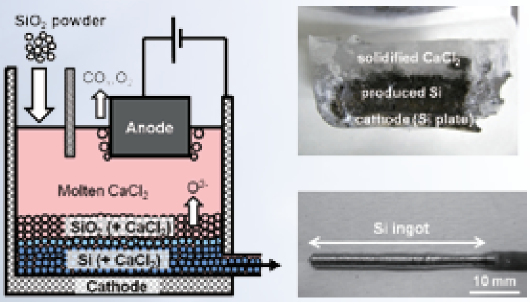
Professor
Toshiyuki Nohira

Associate Professor
Tsutomu Kodaki

Assistant Professor
Takayuki Yamamoto

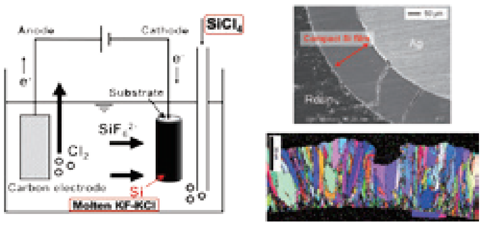
Development of new production processes for solar silicon utilizing molten salt electrolysis

Crystalline silicon solar cells are the most spreading in the world owing to the advantages of high efficiency, high durability, harmlessness for the environment, and abundant resources. Naturally, they are expected to play a major role in the era of full-fledged dissemination of solar cells. However, high purity silicon (or solar-grade silicon, 6N purity), which is necessary for the solar cells, is currently produced by a similar method that was developed for the production of semiconductor- grade silicon (11N purity). A new production method of solar-grade silicon is required because the conventional production method has the disadvantages of low energy efficiency, low productivity, and high cost. From this background, we have proposed a new production method of silicon from the purified silica (SiO_2) feedstock by using molten salt electrolysis. We have already verified the principle of the method, and are now tackling the development of continuous electrolysis process and the improvement of purity. The conventional production process of crystalline silicon solar cells also has several other problems such as the large kerf loss and the complex process of cell production. So, we have proposed a new production method of crystalline silicon fi lm by molten salt electroplating. For this method, we have already confirmed the principle as well. We are now taking on the research on the improvement of film quality and the utilization of $SiCl_4$ as a silicon source.



A new production method of solar-grade silicon by the electrochemical reduction of silica in molten salt

We have proposed a new production method of silicon which utilizes electrochemical reduction of powdery SiO_2 in molten $CaCl_2$ (left). A photo of the sample obtained in the principle verification experiment (top right). A photo of the crystalline silicon rod prepared from the electrochemically produced silicon powder by a floating zone method (bottom right).

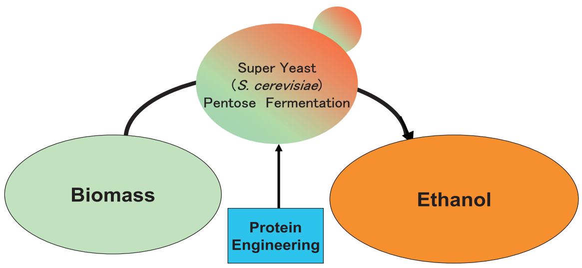


A new production method of silicon films for solar cells by the molten slat electroplating

We have proposed a new production method of crystalline silicon films by electroplating in molten KF-KCl (left). An SEM image of the crystalline silicon film electroplated on a silver wire (top right). An EBSD image of the electroplated silicon film showing its high crystallinity (bottom right).

Highly efficient energy production from biomass

The more efficient use of biomass is demanded to solve the global crises such as exhaustion of fossil fuel and global warming. Our group is focused on the highly efficient production of ethanol from biomass using genetic engineering.



Strategy for construction of efficient ethanol production system from biomass.

Molecular Nanotechnology Research Section

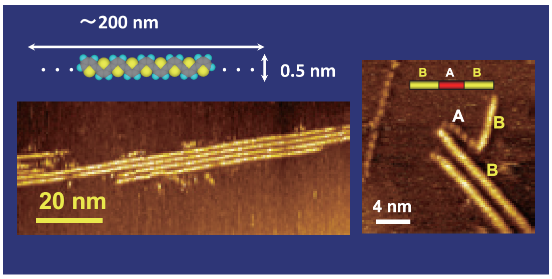
Nanoscience and technology, ultimate method for producing new materials assembling from single molecules, are studied for energy sector such as organic transistors and solar cells.

Professor
Hiroshi Sakaguchi

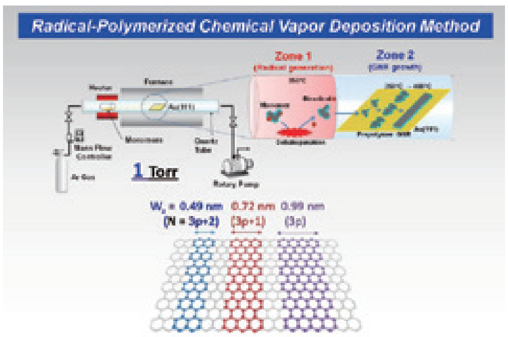
Assistant Professor
Takahiro Kojima

Nanoscience and technology using single molecules

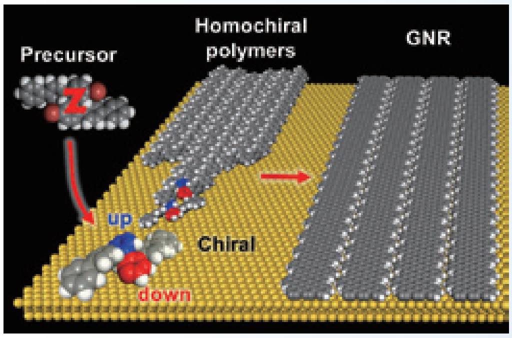
Nanoscience and technology, ultimate techniques for producing new materials assembling from single molecules, are desired to apply in energy sector. Highly efficient devices such as field-effect transistors, solar cells, batteries could be realized by using nanotechnology. We have developed “Electrochemical Epitaxial Polymerization” technique which is a totally new molecular assembling technique of molecular wires on metal surface from single molecules using intense electric field at solid- solution interface (electric double layer). Also, “radical-polymerized chemical vapor deposition” technique which is totally new method to produce grapheme nanoribbons using high concentration of monomer radicals at interface between substrate and gas has been developed. Unprecedented molecular-wire materials consisting of carbon for energy usage will be developed by the use of these techniques. Polycyclic aromatic hydrocarbon molecules for a monomer of molecular wire and for molecular electronics will be synthesized using our new methodology. Organic electronic devices such as field effect transistors, photovoltaics, batteries and photocatalysis will be developed using our new techniques.



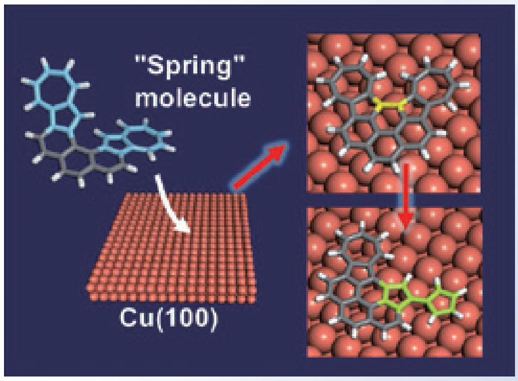
Conducting polymer wires array
Conducting polymer wires array on metal surface by the use of ‘Electrochemical Epitaxial Polymerization’ technique.



Bottom-up synthesis of graphene nanoribbons
Extremely narrow carbon wires developed by our bottom-up surface synthesis technique.



Bio-mimetic surface synthesis of graphene nanoribbons
GNRs can be produced by bio-mimetic principles consisting of chiral transformation, of designed z-bar-linkage precursors, self-assembly, homochiral polymerization and dehydrogenation.

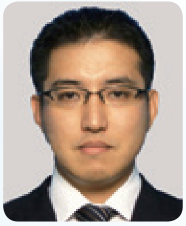


Strain-induced skeleton rearrangement of hydrocarbon molecules on surface
Designed spring molecules on Cu surface can be transformed into the functional flvalene skeleton.

Biofunctional Chemistry Research Section

Our research group is exploring the design and the construction of biomacromolecules “tailored” for pursuing highly efficient energy utilization.

Professor
Takashi Morii



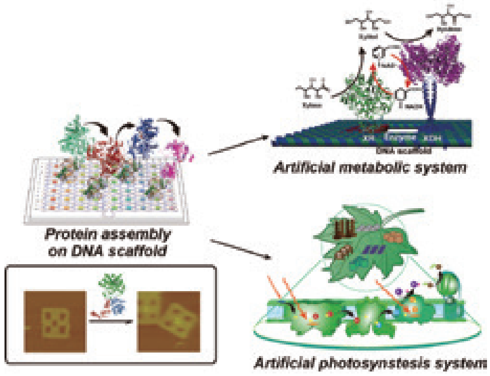
Associate Professor
Eiji Nakata

Assistant Professor
Shun Nakano

A design principle of functional biomolecules for highly effective energy utilization

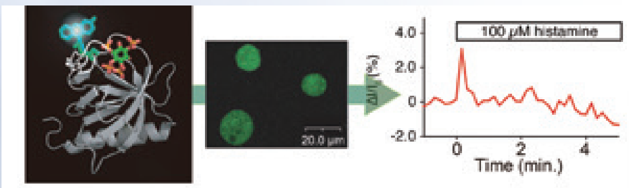
A transition to renewable energy technologies requires new chemistry to learn from nature. It is our challenge to understand the efficient bioenergetic processes of nature and to construct human-engineered energy utilization systems. The research interests in our group focus on the design and assembly of biomacromolecules for energy conversion, catalysis and signal transduction in water, the solvent of life.

We take synthetic, organic chemical, biochemical and biophysical approaches to understand the biological molecular recognition and chemical reactions. Miniature proteins and protein/nucleic acids assemblies are explored to construct artificial biomimetic devices mimicking the function of biological systems, transformation of cellular signals by fluorescent biosensors, directed self-assembly of peptides and proteins, artificial receptors and enzymes based on the complex of RNA and protein, and photosynthesis of chemicals currently made industrially.



Nanoassembly of enzymes and receptors to realize artificial photosynthesis & metabolic systems

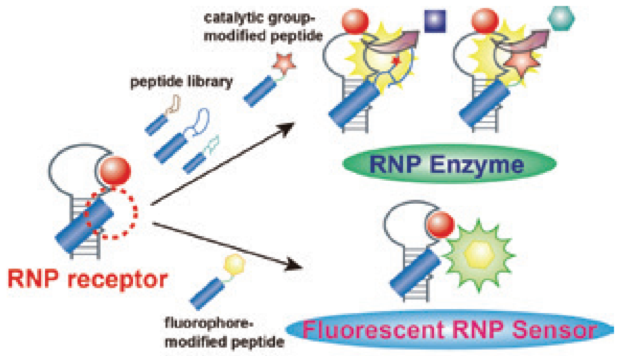
Cellular chemical transformation processes take place in several reaction steps, with multiple enzymes cooperating in specific fashion to catalyze sequential steps of chemical transformations. One is the most popular natural system is photosynthesis system. Such natural systems are effectively reconstructed in vitro when the individual enzymes are placed in their correct relative orientations.
DNA nano-structure such as DNA-origami can be used as “molecular switchboards” to arrange enzymes and other proteins with nanometer- scale precision. A new method was developed based on proteins, to locate specific proteins by means of special “adapters” known as DNA binding proteins. Several different adapters carrying different proteins can bind independently to defined locations on this type of nanostructure. By using the system, nanoassembly of enzymes and receptors will be constructed as the multi-enzymatic reaction system to realize artificial photosynthesis & metabolic systems.



Real-time fluorescent monitoring of IP_4 production in the single cells

Exploring functional biomacromolecules by using RNP complexes

Structure-based design provide alternative strategy to construct protein-based biosensors that assess intracellular dynamics of second messengers and metabolites.



Stepwise molding of functional ribonucleopeptide (RNP) complexes

Exploring functional biomacromolecules by using RNP complexes

Design strategies to tailor receptors, sensors and enzymes are explored by utilizing structurally well-defined protein-RNA complexes. Stepwise strategies of the structure-based design, in vitro selection and the chemical modification afford highly specific receptors for biologically important ligands, such as ATP and the phosphorylated tyrosine residue within a defined amino acid sequence.

Structural Energy Bioscience Research Section

We aim at the establishment of biorefinery through the development of biomass and biomolecules based on structural biology.

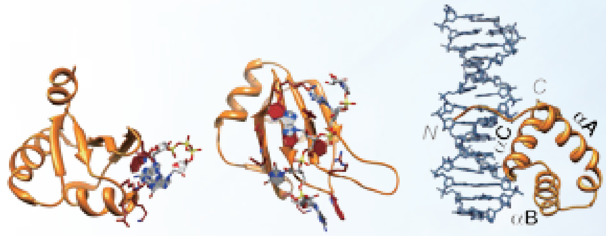
Professor
Masato Katahira

Associate Professor
Takashi Nagata

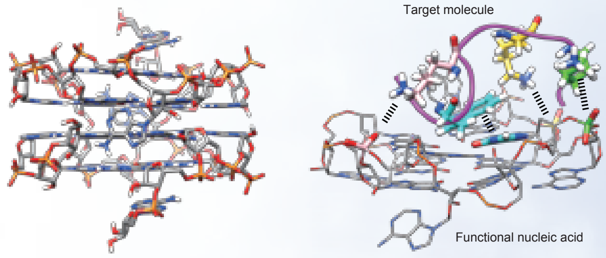
Assistant Professor
Tsukasa Mashima

Toward biorefinery through the development of biomass and biomolecules based on structural biology

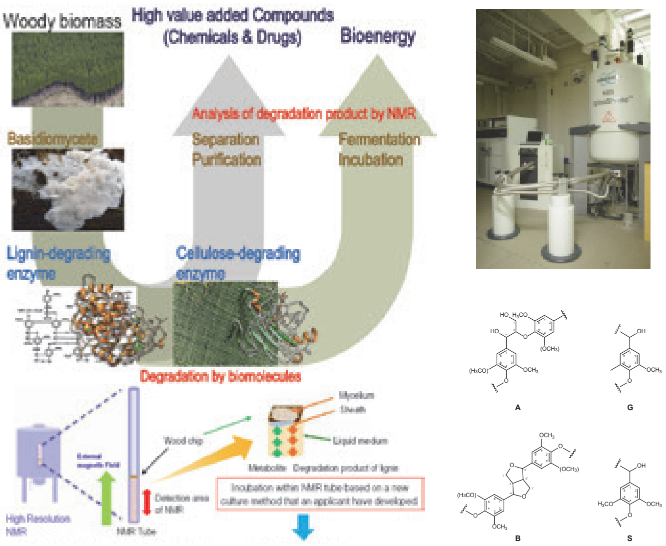
We explore the way how biomolecules such as proteins (involving enzymes) and functional nucleic acids (DNA and RNA) work at atomic resolution based on structural biology with NMR. For example, we have elucidated how functional RNA can trap the protein that causes prion diseases. We are also engaged in development of the new methodology to elucidate the underlying mechanism of functions of these biomolecules. We have successfully developed the way to monitor the base conversion reaction by anti-HIV enzyme in real-time by NMR for the first time. Currently, we are developing the way to extract energy and valuable materials that can be used as starting materials of various products from wood biomass. Thus, we pursue to contribute to the paradigm shift from oil refinery to biorefinery



NMR structures of the protein: nucleic acid complexes
Oogenesis regulator, PARN, is bound to the mRNA 5'-cap (left). Musashi, which maintains pluripotency of the stem cells, is complexed with the mRNA 3' region (middle). GT-1, a light-responsive transcription factor in plants, formed complex with the target DNA (right).



Molecular recognition of biomolecule
A tertiary structure of a functional nucleic acid (left) and its structural basis for recognition of a target biomolecule (right)



Biorefinery based on biodegradation of wood biomass studied by NMR
Establishment of biorefinery on the basis of biodegradation of wood biomass studied by NMR

Advanced Energy Utilization Division

The aim of this research is to construct the supramolecular assemblies of the topologically interlocked components inside a DNA origami. Such assemblies of the functional structures are promising in the fields of molecular switches, motors, sensors, and logic devices.

Junior Associate Professor
Arivazhagan Rajendran

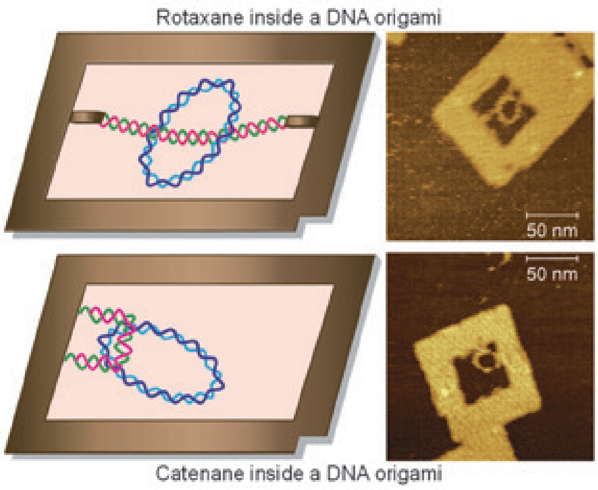
Nanomolecular fabrication of supramolecular assemblies

DNA molecules are not merely associated with genetics and the carrying of information. They have been used as excellent construction units in structural DNA nanotechnology due to their unique structural motifs and robust physicochemical properties. I have been working on the self-assembly of DNA origami (a method to create nanostructures by folding DNA) nanostructures to create micrometer scale structures that can be used for several applications such as fabrication of nanodevices, analysis of biomolecular reactions, and templates for various applications. Also, I have utilized these nanostructures for the single molecule analysis of various biomolecular reactions, structure and function of DNA and proteins, and enzymes related to biomass energy conversion.

Recently, I have been collaborating with the research groups of Prof. Takashi Morii (IAE, Kyoto University) and Prof. Youngjoo Kwon (Ewha Womans University) for the nanofabrication of the topologically interlocked supramolecular assemblies. Topologically interesting structures such as Borromean rings, catenanes, rotaxanes, and knots have been prepared by using duplex DNAs. Also, the complexity of the catenane and rotaxane structures were increased by constructing them by the DNA origami method. However, integration of the duplex DNA catenanes and rotaxanes with functional sequences to the relatively larger and complex DNA nanostructures such as DNA origami has not yet been realized. We have successfully fabricated the DNA catenane and rotaxane structures inside a frame-shaped DNA origami. Apart from the applications in nanotechnology, these interlocked structures can be used for the biomolecular analysis, such as enzymatic reactions and drug screening. For example, these topological structures can be used as the potential substrates for the topoisomerase (Topos) enzymes, and screening of Topo inhibitors.

Among the various types of DNA-binding proteins, Topos are quite attractive due to their importance in cancer therapy. Topos regulate the topological problems of DNA that arises due to the intertwined nature of the double helical structure. These enzymes also play an important role in various biological processes such as replication, transcription, recombination, and chromosome condensation and segregation. Topos resolve the topological problems by transiently cleaving the phosphodiester bond, which generates a Topo-DNA cleavage complex. Once the winding stress is resolved, the Topo-mediated DNA break is resealed. This process is critical for the healthy cells to survive and function normally. Failure to reseal the DNA break can ultimately lead to cell death. This Topo-DNA cleavage complex and various other steps (such as binding of Topo to DNA, ATP driven strand passage, strand cleavage by Topo, formation of Topo-DNA cleavage complex, religation of cleaved DNA, and catalytic cycle after DNA cleavage/enzyme turnover) involved in the Topos function are of great interest as potential targets for the development of anticancer drugs. Despite the development of various Topo-inhibitors, the mechanism of action of these anticancer drug molecules is not well known. Thus, to understand the Topos reaction and the mechanism of the inhibitors, it is necessary to develop an elegant method.

Here, we aim to develop a novel method by using our supramolecular assemblies of the catenane and rotaxane inside a DNA origami and high-speed atomic force microscopy (HS-AFM) for the screening of Topo-inhibitors. The formation of the DNA origami frame and the insertion of the catenane and rotaxane structures were characterized. The Topo reactions and the function of Topo-inhibitors are under investigation. Apart from the Topo reactions and inhibitor screening, the supramolecular assemblies of the topologically interlocked components inside a DNA origami are also promising in the fields of molecular switches, motors, sensors, and logic devices.



DNA rotaxane and catenane inside a DNA origami frame
Left: The illustration of the topologically interlocked DNA rotaxane and catenane inside a DNA origami frame. Right: AFM images of the respective structures.

Self-Assembly Science Research Section

We elucidate a variety of biological self-assembly and structure-formation processes at molecular levels in a unified manner within the same theoretical framework.

Professor
Masahiro Kinoshita

(1) Nonlinear Behavior and Functioning Mechanism of Material Complex System

A material often exhibits high function when it is in contact with or mixed with another material. We refer to a system comprising multiple material constituents as *a material complex system*. Its typical examples are a biological system, colloidal suspension, and solid-liquid interface. The behavior of the system is far from the superposition of behaviors of its constituents and often highly functioning. The research on the system can lead to the exploration of novel technology and the development of new functioning materials. However, it requires the unification of research fields which have separately been systematized, and the collaboration of researchers in different fields is indispensible. In this research section, we have been collaborating with solid-state physicists, electrochemists, and structural biologists on the metal-aqueous solution interface, drastic acceleration of chemical reactions within nanopores using the surface-induced phase transition, mechanism of RNA-protein recognition, and theoretical identification of thermostabilizing mutations for membrane proteins such as the G protein-coupled receptors (GPCRs).

(2) Unified Elucidation of Biological Self-Assembly and Ordering Processes

A variety of self-assembly processes (e.g., protein folding and association) and ordering processes (e.g., different types of molecular recognition, unidirectional movement of myosin along F-actin, and unidirectional rotation of the γ-subunit within F_1-ATPase) occur in biological systems. We wish to systematize a novel theory which enables us to elucidate them within the same framework in a unified manner. The temperature and pressure dependences and the effects of cosolvent and salt addition, which are common in these processes, provide a clue to the systematization. The key factor is the entropic effect originating from the translational displacement of water molecules coexisting with the biomolecules, in particular, biomolecule-water many-body entropic correlations. A hybrid of an integral equation theory and the morphometric approach originally developed by us is a major theoretical tool.

Temperature Plasma Equipment Engineering Research Section

To realize the production of core plasma in nuclear fusion, the physical research and development of heating, control, and diagnostics for high-temperature plasmas.

Associate Professor
Hiroyuki Okada

(1) High Frequency Wave Heating for High Temperature Plasmas

New power sources are being developed for complement of fossil fuel power plants. Fusion power plant using high-temperature plasmas is one of candidates. Our plasma confinement device, Heliotron J is one of torus devices using strong magnetic field. The ion-cyclotron range of frequency (ICRF) heating is applied to it, which utilizes the resonance phenomenon between ions and waves. The ICRF heating produces fast ions. By using such fast ions, the relation of fast-ion confinement to the magnetic field configuration is studied in Heliotron J, of which the magnetic field configuration is changeable using five sets of magnetic field coils.

ICRF antennas

(2) High Density Plasma Production

Plasma particles must be supplied for producing stationary confined plasmas. They are supplied usually by gas injection from the outside of plasmas. However, the gas injection is not so effective since the particles are ionized in the edge region and become plasma particle in poor confinement region. The hydrogen ice pellet is utilized for fueling into plasma core region since it attains deeper penetration. The high-density plasma production and confinement study is performed using pellet injection in Heliotron J.

Environmental Microbiology Research Section (Donation Program)

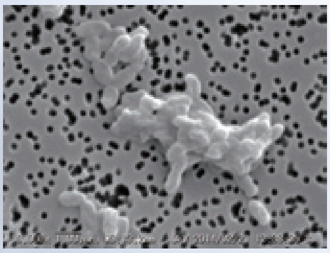
Energy issues and environmental issues are inseparable. We are still highly dependent on fossil energy, and there is concern that discharged greenhouse gases will break the harmony of global environment. In addition, we need large amount of energy to remediate an environmental pollution that remains the shadow of the progress of civilization with fossil fuel energy consumption. As one of the creating methods for sustainable society, we confront the development of practical applications utilizing “enzymes” that are highly energy utilization efficiency in substance catabolism.

Program-Specific Professor
Tomijiro Hara

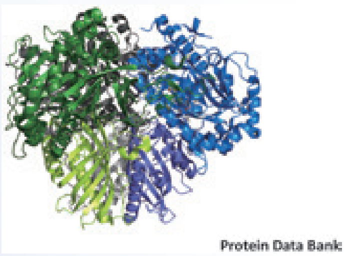
Program-Specific Associate Professor
Yumiko Takatsuka

Establish an optimal process utilizing the oxidation-reduction reactions of enzymes for advanced environmental remediation

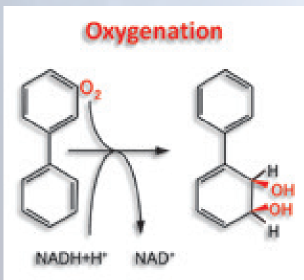
Polychlorinated biphenyls (PCBs) are organochlorine compounds containing theoretically 209 homologs of various chlorine substituents, and it had used in various industrial applications as “dream substance”. However, PCBs has been already promoted globally abolition of the usage and the manufacturing since it was proven human endocrine disruptor. Biphenyl dioxygenase (BDO) plays a crucial role for degradation of PCBs. BDO catalyzes incorporation of two oxygen atoms into the aromatic ring of PCBs, and it induces the ring cleavage. We developed the composite type of catalytic enzymes with two BDOs that having different substrate specificity and the bioreactor for generating oxygen microbubbles that enhancing the enzymatic activity of BDOs. As the result, we succeeded constructing the practical system using both the catalytic enzyme and the microbubbles that degraded over 99% of 40 mg mL^{-1} commercial PCBs in 24 hours. In order to expanding this composite degradable reaction of PCBs, we are trying to create unique artificial enzymes, which reduce PCB by two-electron reduction.



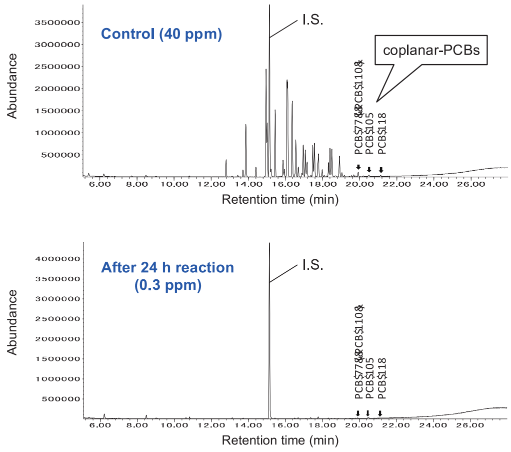
A. Scanning Electron Microscope image of *Comamonas testosteroni* YAZ2 strain which produce biphenyl dioxygenase (BDO). This strain is gram negative and rod-shaped bacterium. Magnification is ×10,000. Scale-bar is 1 μm.



B. Molecular structure model of BDO which catalyze oxygenation reaction toward PCBs (Ref: PDB).



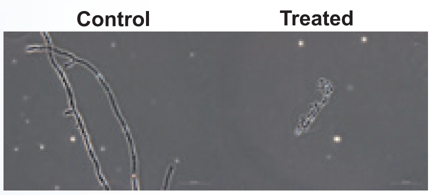
C. Enzymatic reaction showing how BDO hydroxylates one aromatic ring by adding oxygen to biphenyl.



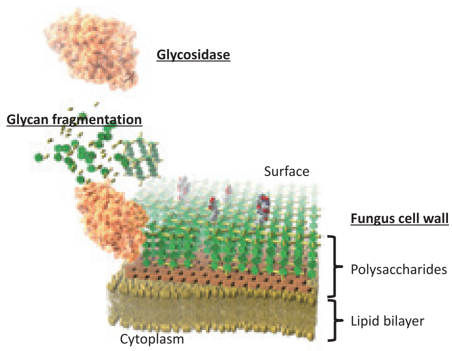
D. The result of reacting 40 mg mL^{-1} of commercial PCBs with composite type of catalytic enzyme, it degraded to 0.3 mg mL^{-1} in comparison with the control (top) within 24 hours (bottom). PCBs was analyzed by gas chromatograph quadrupolemass spectrometer.

Establish an optimal plant disease control methods utilizing enzymatically reaction for an organic food production

Many of plant diseases are generally caused by either ascomycetes or basidiomycetes that belonging to filamentous fungi. “Filamentous fungi” is hypha, and it is proliferated to mycelia. The cell wall is engineered as a composite material. It incorporates a mix of cross-linked fibers and matrix components. The fibrous components of cell wall are glucan, chitin, and mannan, and these sugarchains contribute forming a supple and solid filiform microfibril wall. Glycosidase is one of the hydrolases that catalyzes the hydrolysis of glycosidic bonds in complex sugars. We develop a new bio-molecular type of fungicide utilizing the hydrolysis reaction of glycosidase against fungal microfibril wall. Up to now, our composite type of bacterial catalyst composed of 5 strains from class *Bacilli*, which produce and secrete various glycosidases, controlled 99.3% of a tomato- *Pestalotia disease* with *Pestalotiopsis* sp. Glycosidases are classified into approximately 130 families, and its catalytic reaction is roughly divided into anomeric-inversion and/or anomer-retention, and exoglycosidase or endglycosidase. Hence, the classification of glycosidase can be understood diverse, and we consider that it is possible to digest fungi cell wall efficiently, by compositely capably using these diversities of enzyme reactivity.



E. Morphological study of *Trichoderma viride* MAFF 30546 strain which was treated by enzyme(s) (right) compared with the control (left). Enzyme reaction was carried out at 30°C for 6 hours. *Trichoderma viride* MAFF 30546 strain was stained with lactophenol cotton blue. Magnification is ×400. Scale bar is 50 μm.



F. Image showing how glycosidase digests fungus cell walls.

Adjunct Faculty Members

▶ Advanced Energy Conversion Division　Clean Energy Research Section

Visiting Professor

Ryuta Kasada

Institute for Materials Research,
Tohoku University. Professor

Dr. Ryuta Kasada received his Dr. of Energy Science from Graduate School of Energy Science, Kyoto University in 2001. He spent 16 years at this Institute of Advanced Energy, Kyoto University as an Assistant Professor and an Associate Professor. In 2017, he moved to Institute for Materials Research, Tohoku University as a Full Professor. He studies materials resistant to extreme environments for the next generation base load power plants such as fusion reactor and advanced fission reactors. He also studies new ultra-small testing technologies such as nano-indentation in order to investigate the mechanical properties from nanometer to micrometer of materials placed in extreme environments.

▶ Advanced Energy Conversion Division　Clean Energy Research Section

Visiting Associate Professor

Takeshi Mori

Department of Applied Chemistry,
Kyushu University (Biomedical Chemistry)
Associate Professor

Dr. Takeshi Mori received his PhD from Kyushu University under the direction of Prof. M. Maeda in 2001. He spent four and a half years at Tokushima University as an Assistant Professor. He moved to Kyushu University in 2005 and then promoted to associate professor in 2013. He is interested in application of chemistry to medicine. Current research interests include “chemical transformation” for modification of cellular functions, enzymatic amplification technique for flow cytometry, and molecules to modulate effector functions of antibody.

▶ Advanced Energy Generation Division　Quantum Radiation Energy Research Section

Lecturer (Part-Time)

Kazuyuki Sakaue

Waseda Institute for Advanced Study, Waseda University, Associate Professor

Dr. Kazuyuki Sakaue received his PhD from Waseda University under the direction of Prof. M. Washio in 2009. He spent five years at Faculty of Science and Engineering, Waseda University as a Junior Researcher and an Assistant Professor. In 2015, he moved to Waseda Institute for Advanced Study, Waseda University as an Assistant Professor and Associate Professor. Current research interests include high quality electron beam generation and its application researches. As an application, he is now focused on the radiation from the high quality electron beam and laser-electron interactions.

▶ Advanced Energy Conversion Division　Advanced Energy Materials Research Section

Lecturer (Part-Time)

Hiroki Ago

Global Innovation Center, Kyushu University, Professor

Dr. Hiroki Ago received his PhD from Kyoto University in 1997. He stayed at Cavendish Laboratory, Cambridge University, supported by JSPS during 1997-1999. Then, He worked at National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba as a researcher for four years. In 2003, he moved to Kyushu University as an associate professor and became a full professor in 2016. His current research focuses on exploring science and applications of nanomaterials, particularly graphene and related 2D materials.

▶ Advanced Energy Utilization Division　Biofunctional Chemistry Research Section

Lecturer (Part-Time)

Daisuke Umeno

Department of Applied Chemistry and Biotechnology, Graduate School of Chiba University, Associate professor

Dr. Daisuke Umeno received his PhD from The Kyushu University under the direction of Prof. Mizuo Maeda in 1998. He spent six and a half years in the United State under the supervision of Professor Frances Arnold (Caltech) and Professor Larry A Loeb (UW, Seattle). In 2005, he moved to Chiba University as an Associate Professor. His current research field is evolutionary synthetic biology and his lab. is creating a variety of genetic networks and biosynthetic pathways toward non-natural compounds.

Laboratory for Complex Energy Processes

The Core Institution for Collaboration Research in the Field of Advanced Energy Science and Technology

The Laboratory for Complex Energy Processes

The Laboratory for Complex Energy Processes is a core research center of Institute of Advance Energy (IAE) for multidisciplinary collaboration studies. The Laboratory offers several important functions for the cooperative and ambitious project studies in the field of advanced energy science. The organization of the Laboratory also have technical staffs, and provides the experimental facilities, platforms and supporting functions to promote strategic and innovative collaborative activities.

Objectives

The project studies in the Laboratory are focused on innovative and advanced concepts on the advanced energy science for the sustainability of humankind based on the latest understanding and consideration on the energy and environmental problems. From the strategic consideration, we focus our efforts on two specific priority-fields at the divisions for, (1) "Advanced Studies on Plasma Energy and Quantum Energy" and (2) "Soft Energy Science Research". The multidisciplinary collaboration projects are promoted in these two fields at each divisions with large scale research facilities used for project oriented studies. The third division is established to promote international and domestic collaborative activities with various events, by planning, arranging and supporting function with various partners including governmental institution and industries. Development of human resources in the advanced energy field is also a major function of the university, and as in the past in several educational projects, seminars, internship and courses are included. Bilateral Collaborative Research Program in National Institute for Fusion Science (NIFS), on the study of plasma energy is promoted under the inter-university collaboration. We pursue various types of collaborations with other partners and through these activities, we aim to make a network of energy research for resolving global problems of energy and environment. Moreover, as activities in Kyoto University, we also develop human resources in the advanced energy field.

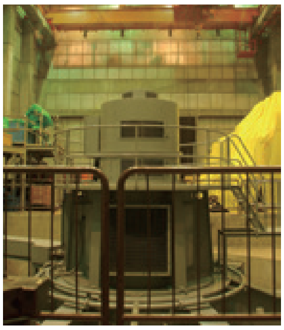
Activities

The Laboratory organizes the cooperative research programs for the scientists from various energy-relating fields inside/outside IAE. The Laboratory also provides the functions for exchanging the scientific information among the collaboration members by organizing or supporting various kinds of symposia, seminars and events for the specific topics on the fields of energy science and technology. A number of significant results have been published from these multidisciplinary collaboration projects in the Laboratory.

The Laboratory has several large-scale research facilities for the collaborations; (1) Advanced energy conversion experimental devices (Heliotron J and DuET), (2) Free electron laser (KU-FEL), (3) NMR facilities, (4) Multiscale testing and evaluation research systems (MUSTER), (5) Compact and portable inertial-electrostatic confinement (IEC) fusion neutron/proton sources, (6) System for creation and functional analysis of catalytic material, etc.

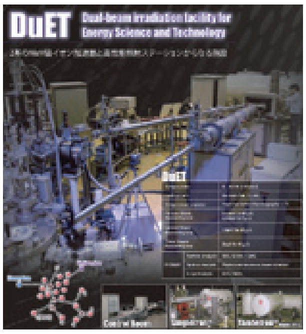
Transmission lines in the laboratory

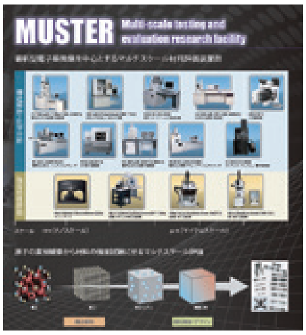
100t crane



Motor generator

The Core Facilities and Equipment of The Laboratory





The Laboratory is consolidating several core facilities for the research programs of the Institute of Advanced Energy. Outlines of the facilities which are described below.

- Heliotron J
  In our Institute, a unique helical device Helitoron J is now in operation, which is based on a Kyoto-University original concept of “helical-axis heliotron”, to investigate the high-level compatibility between (i) good plasma confinement and (ii) MHD stability in the heliotron line. This project is expected to open up a new frontier of the novel plasma parameter regime in the toroidal fusion devices. The major radius of the torus is 1.2 m and the maximum magnetic field strength is 1.5 T.
- DuET/MUSTER Facility
  This facility is for fundamental research on the interaction between materials and multiple charged particles with wide range of energy levels under well-controlled irradiation conditions, as well as for R&D of innovative structural materials through the unique fabrication processes of non-equilibrium and ultra-functional materials. In order to accelerate the achievement of industrial technology innovations, the comprehensive materials/system integration studies have been performed by means of multi-scale evaluation method covering from nano-scaled analysis to the practical size of mechanical tests.
- KU-FEL (Kyoto University Free Electron Laser)
  The KU-FEL provides coherent and tunable laser in Mid-IR region ranging from a 3.6 to 25 μm. The tunable IR laser has been utilized for basic study of high-efficiency solar cells, mass measurement of chemicals from biomass and selective phonon mode excitation in wide-gap semiconductors by collaboration research.
- NMR Facilities
  Four NMR machines, including three 600 MHz machines equipped with super-high sensitivity cryogenic probes, are operated to elucidate the three-dimensional structure and dynamics of biomass and biomolecules at atomic resolution. On the basis of the obtained knowledge, we are developing the way to extract the energy and valuable materials from the biomass and biomolecules.
- Cooperation with industries and national institute by using advanced facilities through Collaborative research office
  Dual-Beam Facility for Energy Science and Technology (DuET), Multi-Scale Testing and Research facility (MUSTER), KU-FEL, and NMR Facilities are open for industries to evaluate materials performance from the viewpoint of multi-scale structure; atomic size, defect size, grain size, etc. to understand the materials behavior in practical applications. Our facilities have supported about 86 companies to contribute in their progress of innovative materials R&D.

Cooperative Research

Besides of an inter-university collaboration program for researchers of energy relating communities, which is promoted by Joint Usage/ Research Center of Zero-Emission Energy Research, IAE, the Laboratory organizes an original cooperative research program for IAE researchers. The Laboratory also provides the functions for exchanging the scientific information among the collaboration members by holding various kinds of symposiums, seminars for the specific topics on the fields of energy science and technology.

Category		No. of adopted subjects
A1	Division of International and Industrial Partnership	5
A2	Division of Plasma and Quantum Energy Research	10
A3	Division of Soft Energy Science Research	9
Total		24

FY 2017 (Apr. 2017 – Mar. 2018)

Organization of Research Projects in the Laboratory

Division of Plasma and Quantum Energy Research

This division promotes studies on advanced plasmas and quantum energy for realizing future energy systems, integrating plasma energy science and advanced energy material research. In particular, based on the results obtained in each related group, we aim at extending the research fields and contributing to human society by utilizing the existing key devices such as Heliotron J, DuET, MUSTER and IEC (Inertial Electrostatic Confinement) device, which have been developed in IAE.

Group of advanced plasma energy control and application research	This group promotes fundamental understanding of self-regulated plasma, development of its control system, putting emphasis on generation of advanced plasma energy from experimental and theoretical viewpoints. Extension and enrichment of plasma energy application are also investigated.
Group of plasma, hydrogen, and material integration research	This group promotes the research on optimization of plasma reaction process in hydrogen cycle and understanding the mechanism of plasma-materials interactions in order to develop highly efficient and controllable energy systems.
Group of advanced energy materials- nuclear systems research	This group promotes the research on nano-meso structure control for high performance materials and materials-systems integration in order to develop innovative energy materials for advanced nuclear energy systems.

Division of Soft Energy Science Research

This division promotes studies on emergent materials and systems for realizing next generation soft energy system. In particular, functional nano- and bio-materials to efficiently utilize solar energy and bio-energy are studied by integrating laser science and expand to THz region, nanotechnology, bio-technology and their combination. We aim at extending our research fields by utilizing the existing devices such as System for Creation and Functional Analysis of Catalytic Materials, SEMs, SPM, Solar Simulator, KU-FEL and various laser systems.

Group of nano-bioscience research	This group aims at the study on the function and the structures of bio molecules from the basic to application level. Understanding the fundamental aspects of molecular recognition, protein folding, enzymatic reactions, and the assembly formation by proteins and nucleic acids will explore a new horizon of the bio energy related nano-bioscience research, such as the development of nano-bio devices that accelerate the efficient utilization of solar energy and the biomass resources.
Group of quantum radiation and optical science research	For contributing to innovative progress in quantum radiation and photon energy science, this group aims at demonstrating potential abilities of light and radiation through the development of advanced coherent radiation sources with novel functions and their applications to materials control and photoreaction dynamics research.
Group of surface and interface science research	This group studies surface science to produce the various functional materials used in energy sector. Surface and interface of matters can be used as a template to synthesize extra-ordinal materials because of their different atomic arrays from the bulk. Research involves in semiconductor porous materials, molecular wires and organic materials for photovoltaic cells in next generation.

Division of International and Industrial Partnership

This division promotes international collaborative research on advanced energy to lead the field of energy science and technology as an international pioneer. For this purpose, the symposium and the workshop organized by institution member are supported. This section also promotes young researcher/student exchange, cooperative research activities and multi-lateral collaborative research with industries. Establishment of infrastructure and human resource development are also supported.

Group of promotion for international collaborative research	This group promotes international collaborative research to solve global issues on advanced energy.
Group of promotion for domestic collaborative research	This group promotes domestic collaborative research to lead advanced energy science and engineering with focusing on human resource development.
Group of promotion for collaborative research with industries	This group supports research projects founded by government and/or industries to accelerate the progress in the researches with high social acceptance.
Collaborative research office	This office member supports industrial research and engineering for energy materials development and materials integration researches as an advanced project with DuET, MUSTER, KU-FEL and NMRs.

Major Projects

A number of projects are currently underway in both scientific and engineering fields of advanced energy to realize a sustainable society that is in harmony with the environment through advanced generation, conversion, and utilization of energy.

Inter-University Research Program (MEXT)

Research Project for Zero-Emission Energy System

- Leader : Director of IAE
- Project Period : the 1st term : FY2011–2015
  the 2nd term : FY2016–2021

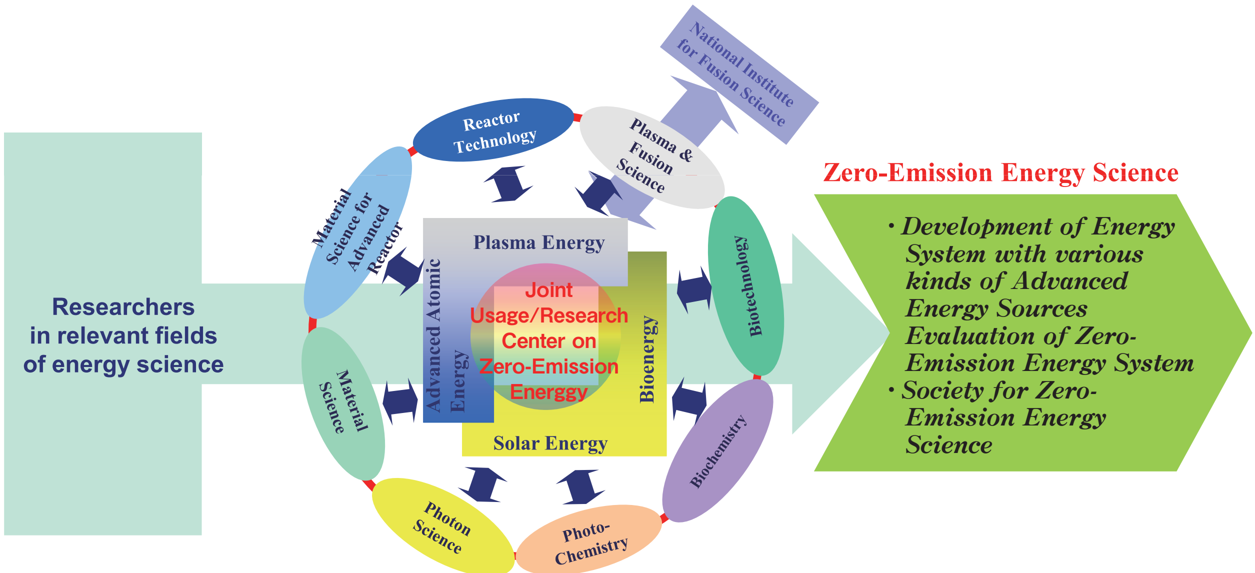
The energy system for next generation should be an environmentally friendly or ecological one, we propose an innovative concept of Zero-Emission Energy. IAE Zero-Emission Energy Research aims at the realization of environmentally friendly energy system for sustainable society with minimum emission of environmental pollutants (Greenhouse Gases, Air Pollutions, Waste Energy, Hazardous Wastes, etc.), and with maximum utilization of energy and resources. This project promotes interdisciplinary researches of energy relevant fields, education and training of young students and researchers in the field of advanced energy science.

Activities in FY2017

- Joint Usage/Research Collaborations:
  Total 100 subjects with 270 Participants from 42 organizations
- International Symposium (September 5-7, 2017)
  "The 8th International Symposium of Advanced Energy Science"
  ~ Interdisciplinary Approach to Zero-Emission Energy ~
- Zero-Emission Energy Network activities for information exchange on Zero-Emission Energy Research.
- Briefing Meeting of Inter-University Collaborations in FY2017 (March 7, 2018).
- Promotions of other Workshops/Seminars of ZE Research.

Joint Usage/Research Center at IAE on "Zero-Emission Energy"

- **To promote interdisciplinary collaboration researches for Zero-Emission Energy Science & Technology,**
- **To explore new horizon of Advanced Energy System for sustainable development,**
- **To promote education & practical training for young researchers.**

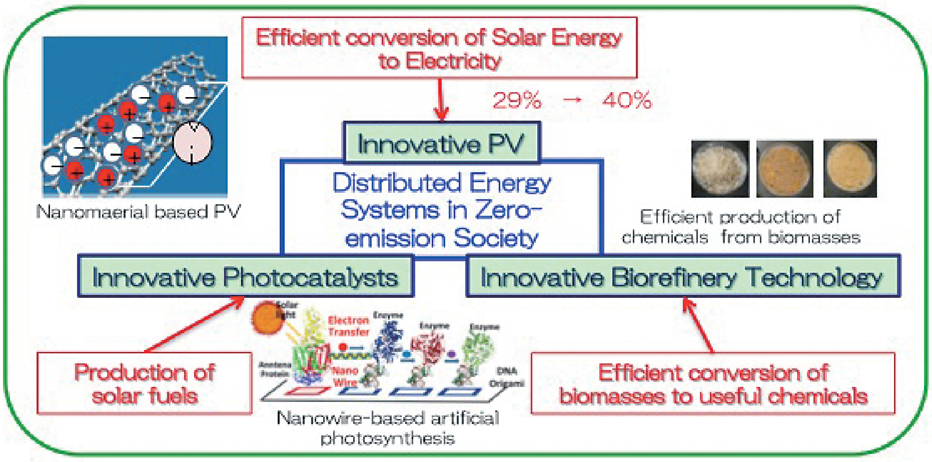


MEXT Special Budget (Project) (MEXT)

Innovative strategy for highly efficient utilization of solar energy
—Exploring novel principles for highly efficient utilization of solar energy—

- Leader : Prof. Takashi Morii
- Project Period : FY2013 – FY2018

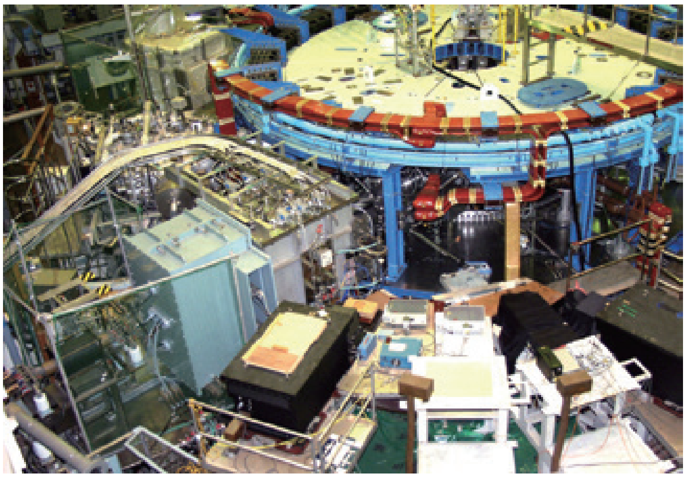
This interdisciplinary research project is aimed to uncover principles that govern highly efficient utilization of solar energy. Four research groups, each based on different disciplines of chemistry, biochemistry, physics and nanotechnology, simultaneously propel the cutting-edge research on the next generation photovoltaic cells, solar fuels, and biorefinery. Research topics include novel solar-light energy utilization by nano-carbon materials, one-dimensional carbon-based polymers for energy utilization, assembly of enzymes on molecular switchboards, development and application of methodology to investigate wood biomass utilization by solution NMR, and applications of mid-infrared laser to investigate the excitation states of nanomaterials. Mutual interactions between the research groups provide an ideal environment to incubate the original ideas, which stimulates creation of an innovative paradigm in solar energy utilization technology.



Bilateral Collaboration Research Program (National Institutes of Natural Sciences)

- Leader : Prof. Kazunobu Nagasaki
- Project Period : FY2004 –

Bilateral collaboration research program promotes joint research bilaterally between National Institute for Fusion Science (NIFS), and the research institutes or research centers of universities that have each unique facility for nuclear fusion research. Under this collaboration scheme, the facilities are open to researchers throughout Japan as a joint-use program of NIFS. Our research subject under this program is to investigate experimentally and theoretically the transport and stability control through advanced helical-field control.



MEXT Special Budget Project (MEXT)

Joint Research Project “Smart-Materials”

- Institute for Chemical Research, Institute of Advanced Energy, Research Institute for Sustainablr Humanosphere
- Project Period : FY2015 – FY2020

Since April of 2015, the Institute for Chemical Research (ICR), the Institute of Advanced Energy (IAE), and the Research Institute for Sustainable Humanosphere (RISH) have been working in cooperation on the “Smart-Materials” project, supported by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan. The ever-increasing demand for materials and energy by the present social system has almost reached its limit, and the environment is heavily burdened by harmful by-products and surplus heat from mass production. In order to overcome these issues, this project aims to fabricate smart materials and develop a joint research organization, achieving green innovation through “zero loss” at the production/transportation/usage of materials/energy. The model for the target materials is a biological system with molecular recognition ability, autonomy, and activity. The key to success is interdisciplinary research with flexibility and rapidity. Taking advantage of the three institutes being located at the same campus (Uji campus of Kyoto University), the under-one-roof scheme is expected to deliver internationally excellent results, contributing significantly to this research field.

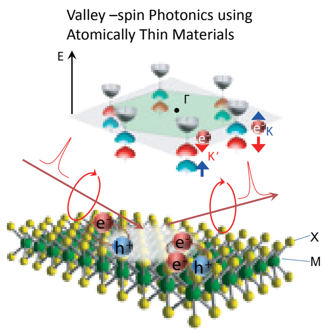
Science and Technology Research Partnership for Sustainable Development (SATREPS: Project Type Technical Cooperation)

Development of clean and efficient utilization of low rank coals and biomass by solvent treatment

- Leader : Specially Appointed Prof. Koichi Miura
- Project Period : FY2013 – FY2018

This project develops new technologies to convert low rank coals and biomass wastes to clean intermediates of low molecular weight compounds using a new concept called “degradative solvent extraction” and to convert the intermediates to new biofuel, solid fuel, and carbon materials. Implementation of the technologies in Thailand and in Asian countries in the near future is also planned.

Grant-in-Aid for Scientific Research (S) in Ministry of Education, Culture, Sports, Science and Technology (MEXT)

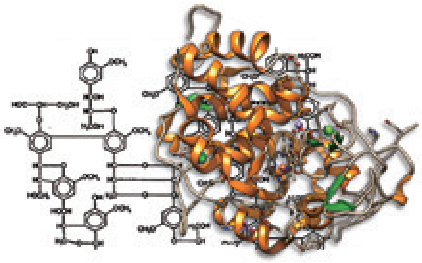


Research area: Science and Engineering (Interdisciplinary Science and Engineering)
Research project: Development and application of valley-spin photonics in atomically thin layered materials

- Project Leader : Prof. Kazunari Matsuda
- Project Period : FY2016 – FY2020

We will study the novel quantum optical phenomena related to the valley-spin and its coherent control by state of art optical spectroscopy in the transition metal dichalcogenides. We would like to develop the new field of valley-spin photonics for optical and material science research.

Strategic Basic Research Programs, Advanced Low Carbon Technology R&D Program (ALCA) Japan Science and Technology Agency (JST)

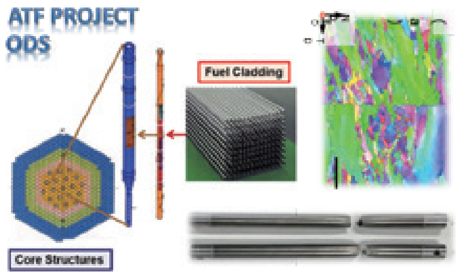


Research area: White Biotechnology
Research project: Advanced lignin degradation with enzymes of marine microorganisms and production of artificial Urushi -Development of highly active enzymes to produce aromatic monomers, GHP/SHP, on the basis of structural biology with NMR-

- Sub-theme Leader : Prof. Masato Katahira
- Project Period : FY2015 – FY2019

METI Project for Development of Technical Basis for Safety Improvement at Nuclear Power Plants

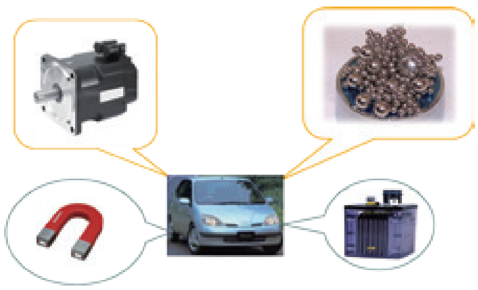
"Development of Technical Basis for Introducing Advanced Fuels Contributing to Safety Improvement of Current Light Water Reactors"



- Leader : Japan Atomic Energy Agency
- Leader in IAE : Prof. Akihiko Kimura
- Project Period : FY2015 – FY2021

Accident tolerant fuel cladding R&D has been conducted to substitute Zircaloy claddings, which are so reactive with hot water that a lot of hydrogen is produced during accident like Fukushima-I, with Fe-based steel. The FeCrAl-ODS steel modified from "Super ODS steel" has been developed for application to the fuel cladding of BWR.

METI Projects to Support the Advancement of Strategic Core Technologies

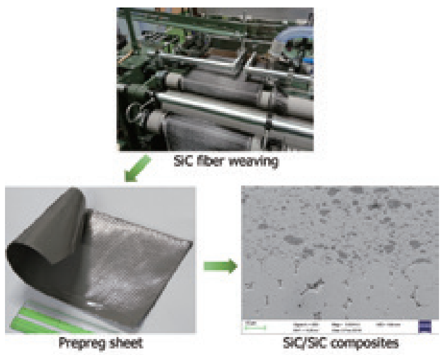


"Development of Massive Production Processing of High Performance Nd-Fe-B Sintering Magnets"

- Leader : Specially Appointed Professor Masato Sagawa
- Project Period : FY2016 – FY2018

The development of the world No. 1 magnet has been conducted. The demands for Neodymium magnet has rapidly growing and the massive production processing of Nd-Fe-B magnets are highly required by many fields of magnet users. The evaluation methodology of nano/mezo structure control towards high performance is progressing.

METI Projects to Support the Advancement of Strategic Core Technologies



"Development of Production Process of SiC/SiC composites for High Efficiency Aircraft Engine"

- Project Leader : Mr. Yonezo Miyamoto, Marui Orimono Co.,Ltd.
- Sub-Project Leader : Assoc. Prof. Tatsuya Hinoki
- Project Period : FY2017 – FY2019

It is expected to utilize SiC/SiC composites for the next generation aircraft engine material due to light weight and high temperature mechanical properties. The project aims to develop the superior material to a conventional material in terms of high temperature mechanical properties and low cost. The project includes development of weaving technique of SiC fibers, prepreg sheet, shaping, production process and evaluation technique.

Research Unit for Smart Energy Management

- Leader : Prof. Yasuo Okabe (Academic Center for Computing and Media Studies)
- Leader in IAE : Prof. Toshiyuki Nohira
- Project Period : FY2016 – FY2021

This research unit aims to enhance the interdisciplinary R&D on Smart Energy Management by developing and deepening the various results obtained in Graduate School of Engineering, Graduate School of Energy Science, Institute of Advanced Energy, Graduate School of Economics, Graduate School of Informatics, and Academic Center for Computing and Media Studies, Kyoto University. The unit especially focuses on the fusion of current communication network technology and information processing technology. The unit will also conduct cooperation research projects with industry, government, schools.

Kyoto University Research Coordination Alliance, Research Units for Exploring Future Horizons

Under the Kyoto University Research Coordination Alliance, 4 projects are ongoing as the organization "research unit", where IAE is involved in 2 projects.

Unit of Academic Knowledge Integration Studies

- Leader : Prof. Seiichiro Hara (Center for Integrated Area Studies)
- Leader in IAE : Prof. Hideaki Ohgaki
- Project Period : FY2015 – FY2019

In this program, 15 departments collaborate to integrate academic knowledge accumulated in Kyoto University by using an advanced information technology, especially on database. The unit studies an interdisciplinary field of the digital-humanism targeting on the human security problems in south-east Asian countries as a practical field. The goal of the program is to offer an academic "big data" system to integrate the social science and natural science.

Unit for Development of Global Sustainability

- Leader : Prof. Sumio Matsuura (Research Unit for Development of Global Sustainability)
- Steering director of IAE : Prof. Masato Katahira
- Project Period : FY2014 – FY2019

The Institute of Sustainability Science, which pursued sustainability study in the past 10 years by the collaboration of 7 departments, has reformed itself into "Unit for Development of Global Sustainability". This research unit aims at exploring and developing the idea and method of such plans focusing on the lifetime, on the basis of interdisciplinary collaborative researches.

Research Facilities

The Institute of Advanced Energy conducts research at several buildings, including the main building on the Uji Campus.

Laboratory for Energy Nano-science (IAE, Bldg. N-1)

Laboratory for Photon and Charged Particle Research (IAE, Bldg. N-2)

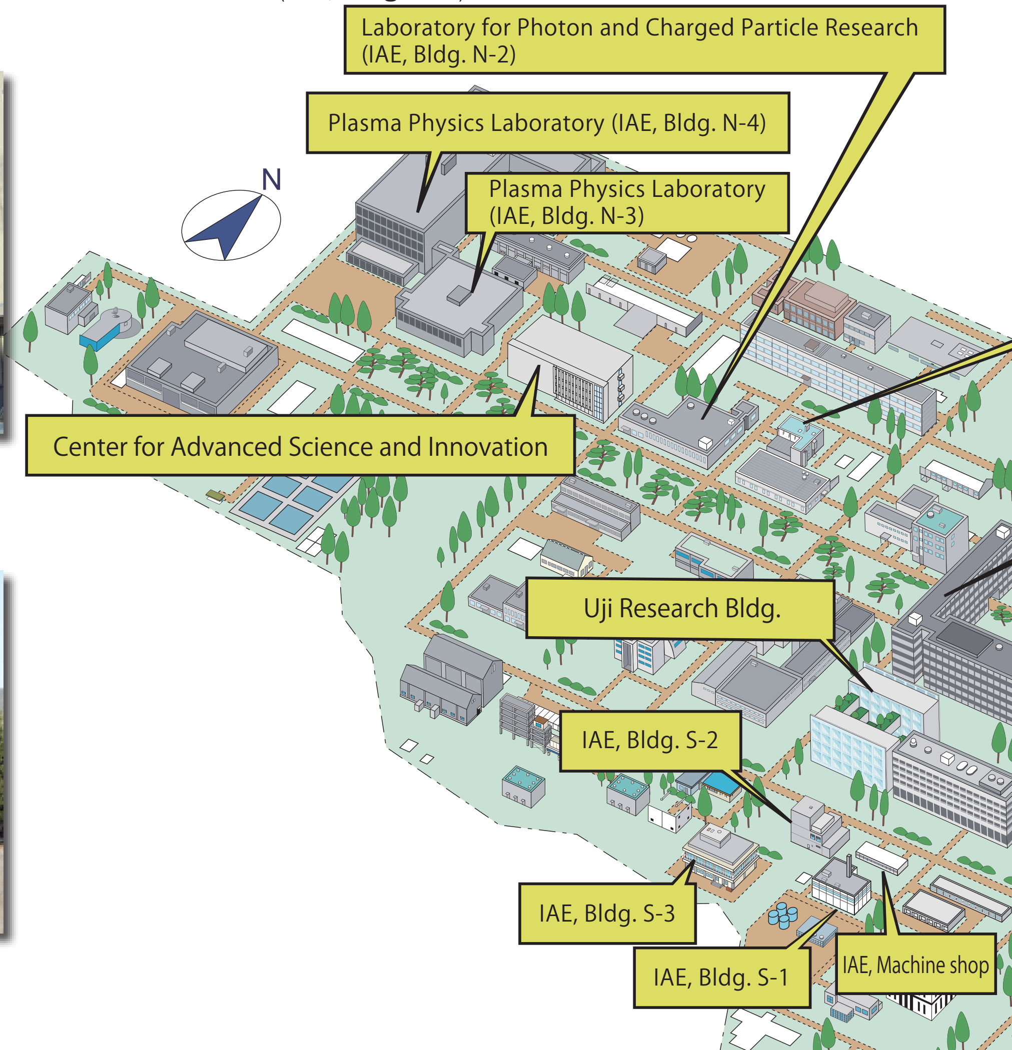
Plasma Physics Laboratory (IAE, Bldg. N-3)

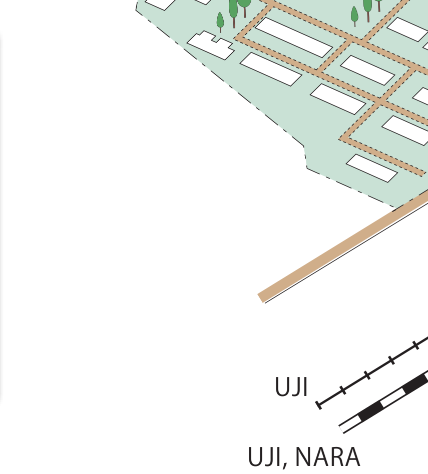
Uji Campus Main Bldg. (W wing)

Uji Campus Main Bldg. (M wing)

IAE, Bldg. S-1

IAE, Bldg. S-2

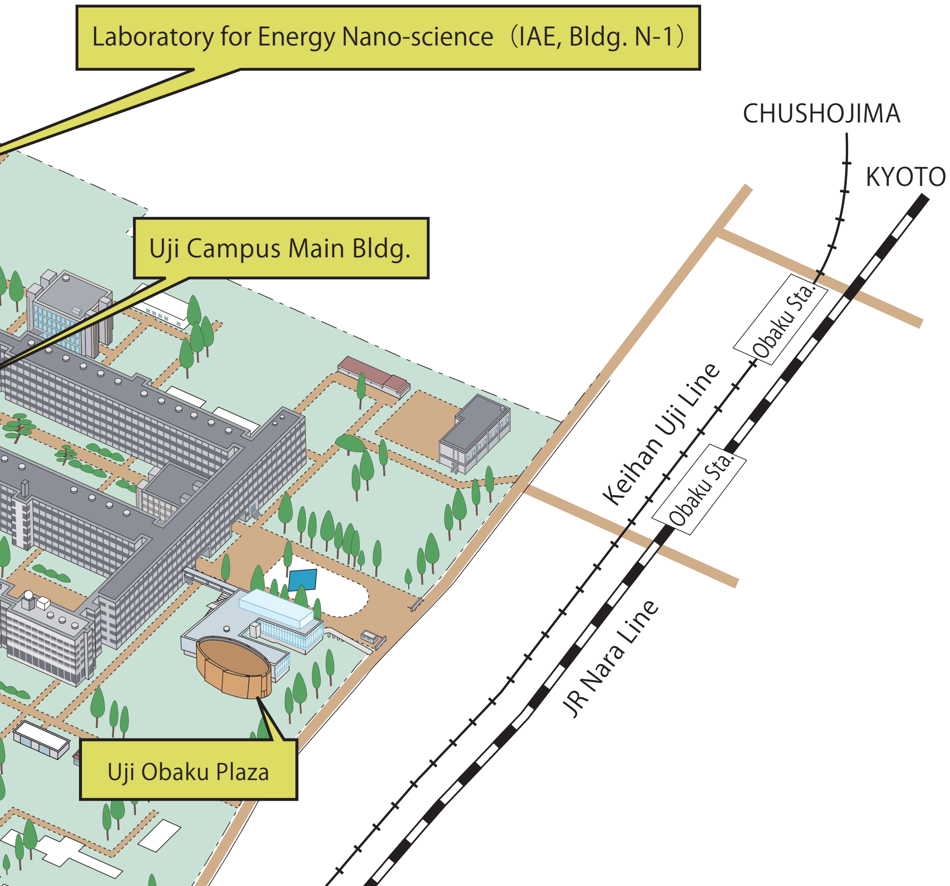




Plasma Physics Laboratory (IAE, Bldg. N-4)

Center for Advanced Science and Innovation

Uji Research Bldg.



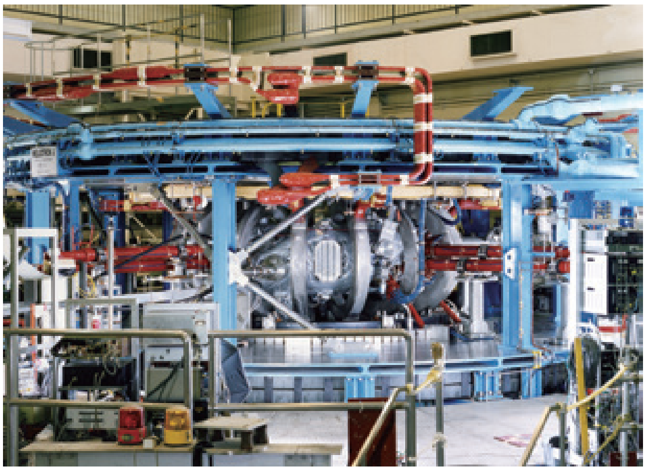
Uji Obaku Plaza

IAE, Bldg. S-3

IAE, Machine shop

Heliotron J

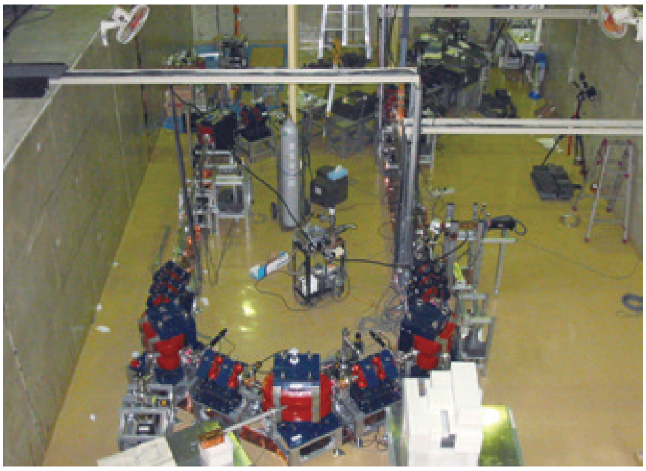
One of the objectives of the Heliotron J project is to explore the confinement optimization of the "helical-axis heliotron" configuration which is original to Kyoto University in its design concept, in order to develop the advanced and high-performance fusion reactor. Heliotron J started its plasma operation in 2000, and continues the improvement of performance as a unique fusion plasma experiment device.



(IAE, Bldg. N-4)

Mid-infrared Free Electron Laser Facility KU-FEL

KU-FEL is a tunable MIR laser which is generated by a relativistic electron beam interacted with synchrotron radiation in the periodic magnetic field. Researches on energy materials by using high peak power MIR-FEL have been conducted by cooperation researchers.



(IAE, Bldg. N-2)

Dual-Beam Facility for Energy Science and Technology DuET

DuET is a powerful tool for introduction of lattice defects, modification of surface structure, and in-beam analysis. Two ion-beams of a different species are able to be irradiated simultaneously to the metals and/or ceramics under various environmental conditions.

(IAE, Bldg. N-2)

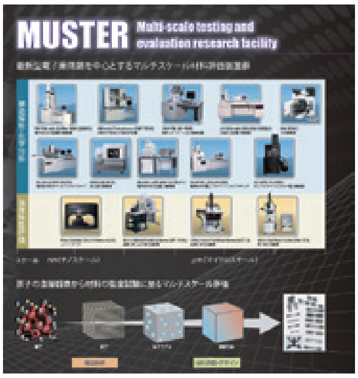
NMR Machines

Four NMR machines, including three 600 MHz machines equipped with the superhigh sensitivity probe, are operated to develop the way to extract the energy and valuable materials from biomass and biomolecules.

(IAE, Bldg. S-2)

Multi-Scale Testing and Research Facility MUSTER

MUSTER is a research facility installed with high-resolution microscopes, TEM, FE-TEM, SEM and FE-SEM, chemical analyzers, FE-AES and FE-EPMA, and mechanical testing machines, fatigue test machine, impact test machine, high temperature tensile test machine and nano-indenter, etc.



(IAE, Bldg. N-1, N-2)

Research Facilities for Energy Nanoscience

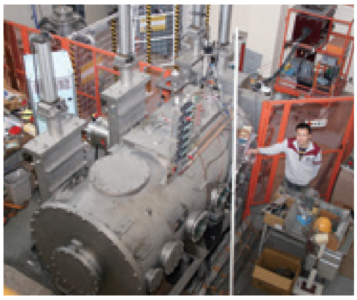
Analytical instruments for investigation of the energetic function of nano-composites and biomaterials are provided. These involve scanning probe microscopes, atomic force microscopy, fluorescence microscope, CD spectrometer, ultraviolet and visible spectrophotometers, a fluorescence spectrometer, iso-thermal titration calorimetry, differential scanning calorimetry, MALDI-TOF mass spectrometer, ESI mass spectrometer, FT-IR spectrometer and photo-electron spectroscopy. (IAE, Bldg, Main Bldg.)

Functional Analytical Systems for the Generation of Catalytic Materials

Instruments are set up to purify, analyze chemical compositions and structures, and to evaluate functions of various biomolecules, organic and inorganic molecules. These include 300 MHz and 600 MHz NMRs, a protein purification chromatography system, a DNA sequencer, a time-resolved fluorescence spectrometer, a FESEM, and a solar simulator. (IAE, Bldg. N-1, Bldg. S-1, Main Bldg.)

Fusion In-vessel Components Experiment Device

Conditioning of 30kV-6A hydrogen beam and development of neutron source is ongoing for the research of innovative concepts of high heat flux divertor and breeding blanket for fusion in-vessel components based on liquid metal and other unique materials.



(IAE, Bldg. S-3)

Advanced Energy Conversion Experiment

For the evaluation of heat flux plasma facing components and high temperature blanket, a 950 C LiPb liquid metal loop and compact fusion neutron source are developed. Study on interaction between material and energy on the energy conversion components with advanced materials and heat transfer media will be performed.

(IAE, Bldg. S-1)

CEP-Stabilized High-Intensity, Ultrashort-Pulse Laser

This Ti:sapphire laser using the chirped-pulsed amplification technique produces intense few-cycle optical pulses with stabilized carrier-envelope-phase, which allows us to approach new strong-field and attosecond regimes in studying interaction of light with matter.

(Uji Campus Main Bldg.)

Education and Social Activities

The Institute strives to train graduate students who are specialists with a global perspective capable of solving energy issues in the twenty-first century.

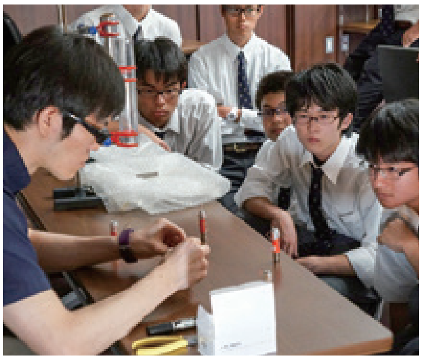
Education

Since being simultaneously launched with the Graduate School of Energy Science, Kyoto University in 1996, each laboratory in the Institute has participated in training graduate students via a cooperative course. The steady flow of research achievements has been attracting more and more students to our Institute. Both the recent increase in the number of Ph.D. students and the higher percentage of foreign students in our student body attest to the fact we are becoming an international institute. Additionally, many of our graduate students are attracted to the Institute's unparalleled quality of advanced equipment and the diversity of our staff engaging in advanced research.

We hold briefing sessions for prospective graduate students in conjunction with Graduate School, so that potential students are familiar with issues such as our enrollment policy and selection procedure. The notable activities of our Institute include briefing sessions of our graduate school, which have been held concurrently with our open seminars, to disseminate our activities to a broad audience. These efforts have increased the student body at our Institute to 92 in FY2017, which includes 33 Ph.D. students (22 from foreign countries). We are leveraging both the Institute's Research Assistant (RA) system to increase opportunities for graduate students to network with other research institutes in Japan and abroad as well as to encourage them to present at research meetings in and out of Japan. To broaden their international perspective, many of our graduate students have participated and/ or presented at international conferences. Attending international conferences plays a major role in our training activities at the Institute. We are also making efforts to expand the professional careers of our graduates, and numerous graduates have found employment at research institutes in Japan and abroad. Additionally, we jointly host public lectures with technical colleges to further our education and training activities.

We also strive to include the general public in our activities via public lectures and an open campus policy. Visitors are always welcome. We aim to contribute to a broad spectrum of our society, including the local public activities. Additionally, the latest information is disseminated through the Institute's website, annual reports and publicity activities of the University. Since 2003, we have held annual public lectures on our campus and in the city of Kyoto to facilitate participation from the general public.

We also actively participate in Kyoto University Research Institutes' Symposium to impart our achievements. Moreover, efforts have been made to develop innovative and creative initiatives of the advanced energy fields and training activities in the nuclear power field. We are dedicated to disseminating and practically applying intellectual properties through activities such as i) collaborating with industry, government, and academia, ii) holding joint symposia, iii) actively conducting collaborative research and engaging in commissioned research, iv) providing technical guidance to industry, and v) implementing systems for the effective collaboration of industry, government, and academia. Results from these initiatives will be used in a broad array of fields to further our contributions in the international arena and to strengthen our international collaborative network.

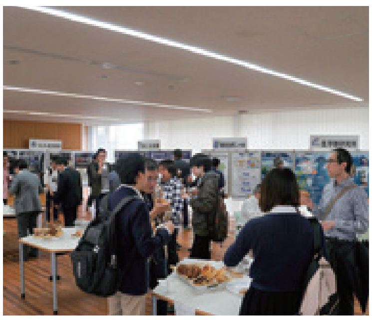


International Symposium of Advanced Energy Science "Interdisciplinary Approach to Zero-Emission Energy"

The 8th International Symposium of Advanced Energy Science titled "Interdisciplinary Approach to Zero-Emission Energy" was held at the Kyoto University Uji campus for 3 days from 5th September 2017. The symposium was supported by Joint Usage/Research Center Program of MEXT, jointly held with the International Workshop on Energy Science Education. We had 17 distinguished speakers from home and abroad in the field including bioenergy, nuclear fusion, optics, material science, nanotechnology, solar energy and more. We also had 99 poster presentations. The symposium gathered 342 participants from all over the world. Specialized and detailed discussion was carried out at the parallel seminar sessions, which has successfully satisfied the participants who wished to discuss in more depth.

Public Lectures

"The 22nd Public Lecture of Institute of Advanced Energy" was held at Kihada Hall of Obaku Plaza on Uji campus on May 13th, 2017. This series of annual public lectures have been held to introduce our recent research activities to the public including industrial workers, college students, high school and junior high school students, etc. In the opening address, Y. Kishimoto, the director of institute, introduced current status and feature prospect of energy research in our institute. Four professors introduced their recent research activities in an easy-to-understand manner. H. Zen gave a talk on "Strong Light That Illuminates the Secret of Energy: Free-Electron Laser", H. Okada presented "Energy from Plasma", T. Kodaki talked on "Do You Know Biomass-Energy?", and finally T. Nakae lectured "Assembling the "Electricity Generating" Carbon-Ribbons by Using the Surface of Gold". T. Morii, the vice director, concluded the session with closing remarks showing appreciation to participants. After the lectures, poster presentations and laboratory tour were conducted for the participants.



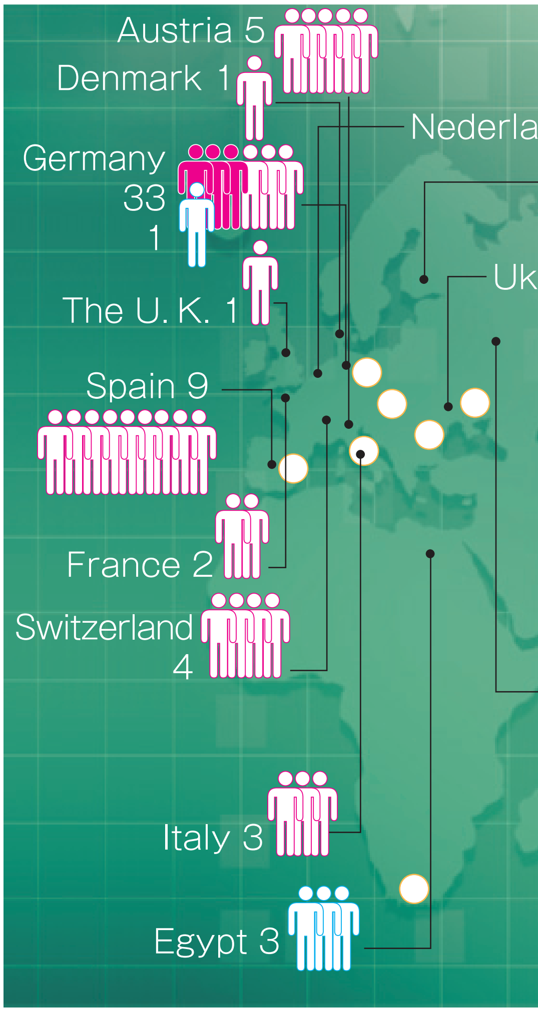
International Activities

We have signed collaborative research agreements with numerous research institutes around the world to actively conduct joint research, including research visits and international conferences.

Academic Collaboration Agreements

Date signed	Name of Institute	Country
Sep. 29, 1995	Fusion Technology Institute, University of Wisconsin-Madison	U.S.A.
Oct. 3, 1995	Fusion Studies Laboratory, University of Illinois Urbana-Champaign	U.S.A.
Oct. 6, 1995	Russian Research Centre "Kurchatov Institute"	Russia
Nov. 6, 1995	Center for Fusion Science, Southwestern Institute of Physics	China
Jun. 3, 1996	Institute of High Energy Physics, Chinese Academy of Sciences	China
Jun. 4, 1996	China Institute of Atomic Energy	China
Nov. 19, 1996	Center for Beam Physics, Lawrence Berkeley National Laboratory, University of California	U.S.A.
Nov. 20, 1996	Free Electron Laser Center, Hansen Experimental Physics Laboratory, Stanford University	U.S.A.
Dec. 12, 1996	Department of Physics, Flinders University of South Australia	Australia
Mar. 10, 1997	Institute of Material Failure, University of Science & Technology, Beijing	China
Aug. 10, 1997	Plasma Research Laboratory, Australian National University	Australia
Feb. 6, 1998	Torsatron/Stellarator Laboratory, University of Wisconsin-Madison	U.S.A.
May. 11, 1998	National Science Center 'Kharkiv Institute of Physics and Technology'	Ukraine
Aug. 1, 1998	Department of Materials Science and Chemical Engineering, Politecnico di Torino	Italy
May. 7, 1999	Industry-University Cooperation Section, Dong-eui University	Republic of Korea
July. 24, 2000	Dong-eui University (Engineering school)	Republic of Korea
Sep. 10, 2000	Korea Basic Science Institute	Republic of Korea
Jan. 9, 2001	Graduate School of Physics, University of Sydney	Australia
Jan. 25, 2001	Slovak University of Technology in Bratislava (Faculty of Electrical Engineering and Information Technology)	Slovak Republic
Jan. 5, 2001	Rajamangala University of Technology Thankyaburi	Thailand
May. 16, 2001	Spanish National Research Centre for Energy, Environment and Technology, CIEMAT	Spain
July. 24, 2001	University of Erlangen-Nuremberg (Department of Material Science, School of Engineering)	Germany
Apr. 6, 2006	National Fusion Research Institute	Republic of Korea
Nov. 28, 2006	Research Institute of Industrial Science and Technology, Pukyong National University School of Engineering	Republic of Korea
Feb. 20, 2009	Atomic Energy Materials, Global Security, Lawrence Livermore National Laboratory	U.S.A.
Oct. 19, 2009	Joint Graduate School of Energy and Environment	Thailand
May.18, 2010	City University of New York, Energy Institute	U.S.A.
Apr. 12, 2012	Nano and Energy Center, Vietnam National University, Hanoi	Vietnam
Jan. 23, 2013	Fusion Plasma Transport Research Center, Korea Advanced Institute of Science and Technology	Republic of Korea
Mar. 20, 2013	Korea Atomic Energy Research Institute	Republic of Korea
Oct. 29, 2013	The Convergence of It Devices Institute Dong-Eui University and Ulsan Technopark	Republic of Korea
Sep. 18, 2014	Center for Advanced Material & Energy Sciences, University Brunei Darussalam	Brunei
Oct. 6, 2014	Horia Hulubei National Institute of Physics and Nuclear engineering	Romania
Dec. 1, 2014	Nelson mandela metropolitan university	South Africa
Dec. 3, 2014	Ulsan National Institute of Science and Technology (UNIST), Fusion Plasma Stability and Confinement Research Center (FPSCRC)	Republic of Korea
Jun. 15. 2016	Center for Science and Technology of Advanced Materials, Indonesia National Nuclear Energy Agency-Batan	Indonesia
Jul. 7. 2016	University of California, Santa Barbara	U.S.A.
Jul. 28. 2016	IAEA (International Atomic Energy Agency)	Austria

The number of visitors



International Exchange Promotion: ASEAN-JAPAN

▶ **Leader: Prof. Hideaki Ohgaki**

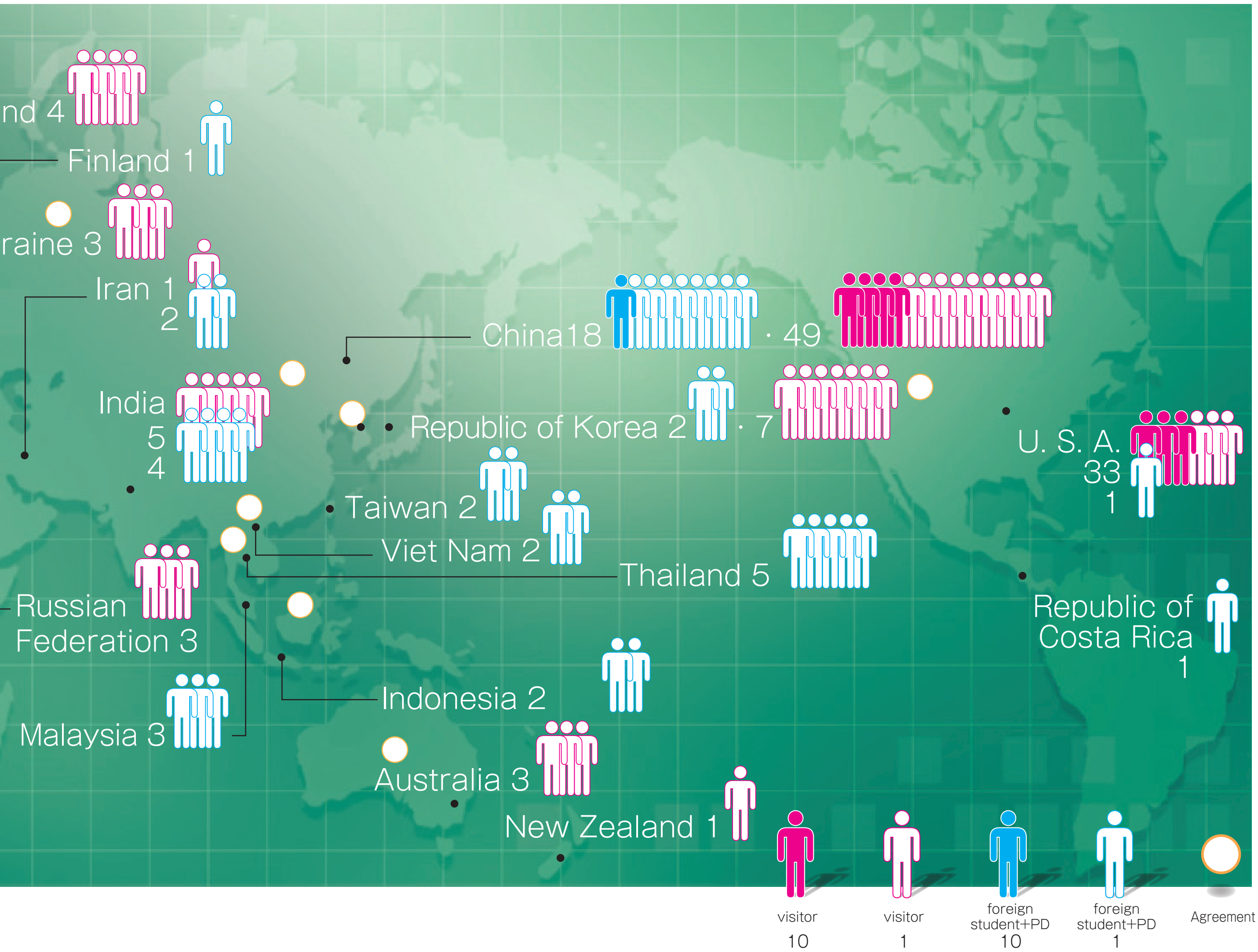
International exchange promotion activities among ASEAN countries are started by the 21st century COE program from 2006 through establishing the Asian academic network named SEE Forum (Sustainable Energy and Environment Forum). In 2018, we will have the special session of the SEE Forum in the Grand Renewable Energy 2018 in Yokohama in June. In Thailand we also have the Eco-Energy and Materials Science and Engineering Symposium (EMSES) in almost every year in cooperation with Rajamangala University of Technology Thanyaburi from 2001. In this year, 14th EMSES will be held in Uji Campus, Kyoto University in co-organized with National Institute of Technology, Kagawa College. By this co-operation we foster energy researchers in ASEAN countries.

These international activities among ASEAN region have been appreciated by many the counterpart universities, research institute in Asia, Japanese government and UNESCO. In this connection we started to cooperation with UNESCO COMPETENCE program from 2009. As the extension activity we started the ODA-UNESCO Assist program on Energy for Sustainable Development in Asia (Vietnam in 2011, Laos in 2012, Cambodia in 2013, and Myanmar in 2014, http://www.oda-unesco-iae-kyoto-u.com/). In 2017, UNESCO selected Kyoto University as "UNESCO chair" in the field of water, energy, and disaster prevention. In 2015, the Japan ASEAN Science and Technology Innovation Platform (JASTIP) has been adopted in JST SICORP and we have been promoting the international collaboration research between Japan and ASEAN.

In education activity, based on the MOU between Kyoto University and AUN which was initiated IAE activities, the AUN – KU Student Mobility Program towards Human Security Development (HSD) has been selected to accelerate internationalization of university in 2012.

JASTIP WP2 Kick-off workshop held in NSTDA on Feb. 29, 2016.

and foreign students (2017)



JSPS/NSFC Bilateral Collaboration Research Program "Research on Coherent Synchrotron Radiation and Super-radiation Free Electron Laser based on Ultra-Short Electron Bunches"

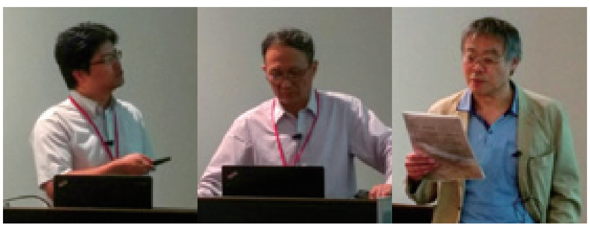
▶Leader : Prof. Hideaki Ohgaki

▶Period : From April 1, 2016 to December 31, 2018

This collaboration research aims at developing intense coherent radiations from high brightness electron beams in cooperation with Japan (Kyoto University and Tohoku University) and China (University of Science and Technology China, and Peking University).

Japanese team will mainly work on experimental study on generation of ultra-short bunch electron beams and coherent radiations. Chinese team will mainly work on theoretical study of these topics as well as development of simulation code.

In Kyoto University, the existing 40 MeV electron linac where we can generate intense coherent synchrotron radiation and a newly installed small photocathode rf-gun based THz radiation machine will be used for this program. In Tohoku University, the originally designed thermionic rf-gun based linac will be studied in this program. In Peking University, the super-conducting linac which can generate strong coherent radiation will be studied. In University of Science and Technology Chine, theoretical studies will be carried out to understand the generation of ultra-short bunch electron beams with rather low energy (a few to 50 MeV) as well as generation of coherent super-radiation including development of simulation code. From 2017, NSRL has started installation of a new FEL machine and Japan side team will also contribute to the machine commissioning and FEL lasing in NSRL.

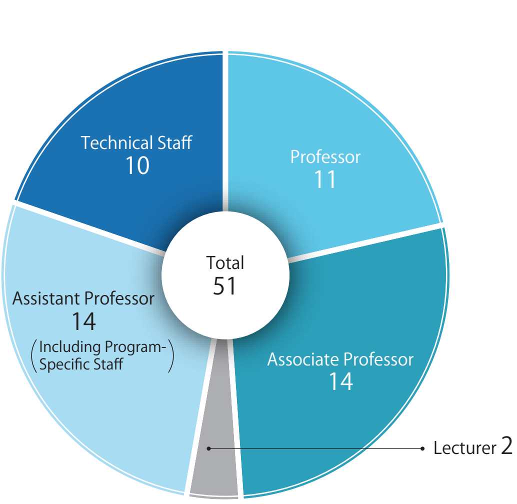


2nd International workshop on CSR and free electron lasers from ultra short bunch electron beam held in Tohoku University from September 19 to 20, 2017

Data

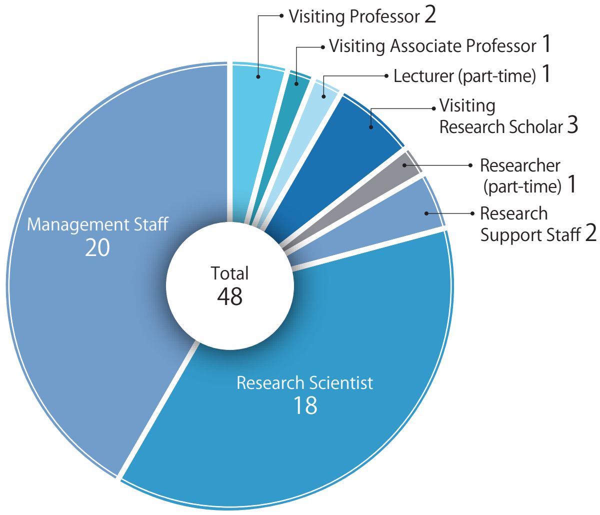
Faculty Member

2017



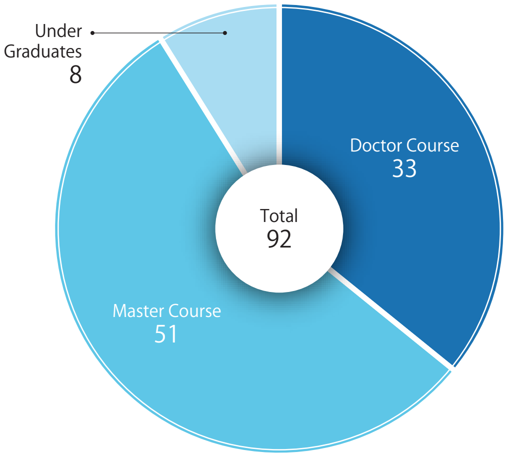
Adjunct Member

2017



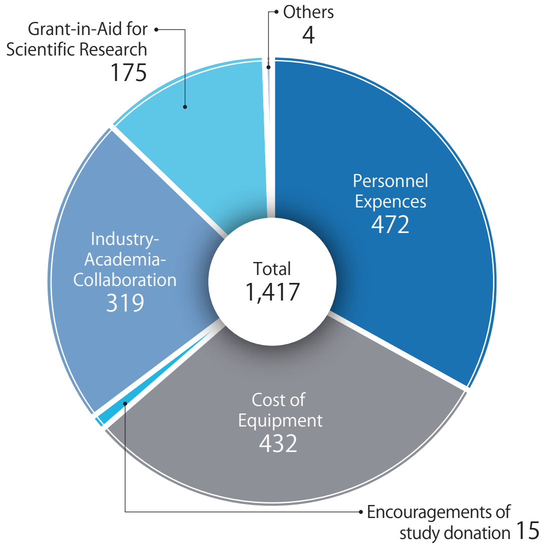
Students

May. 2017

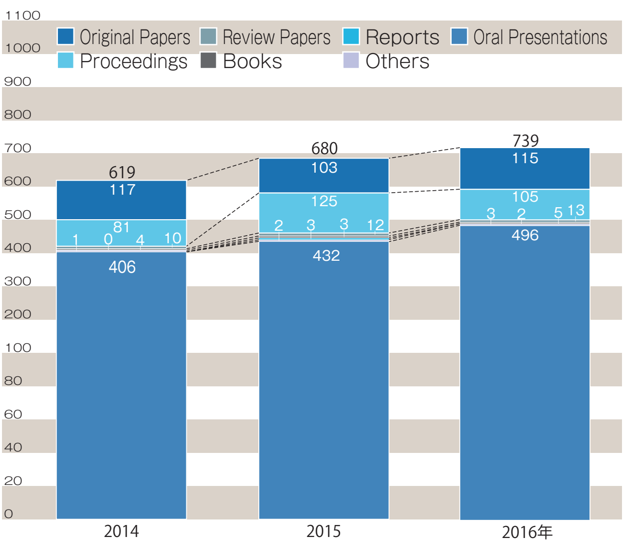


Budget

FY2016 [unit: 1 million yen]



Research Presentations

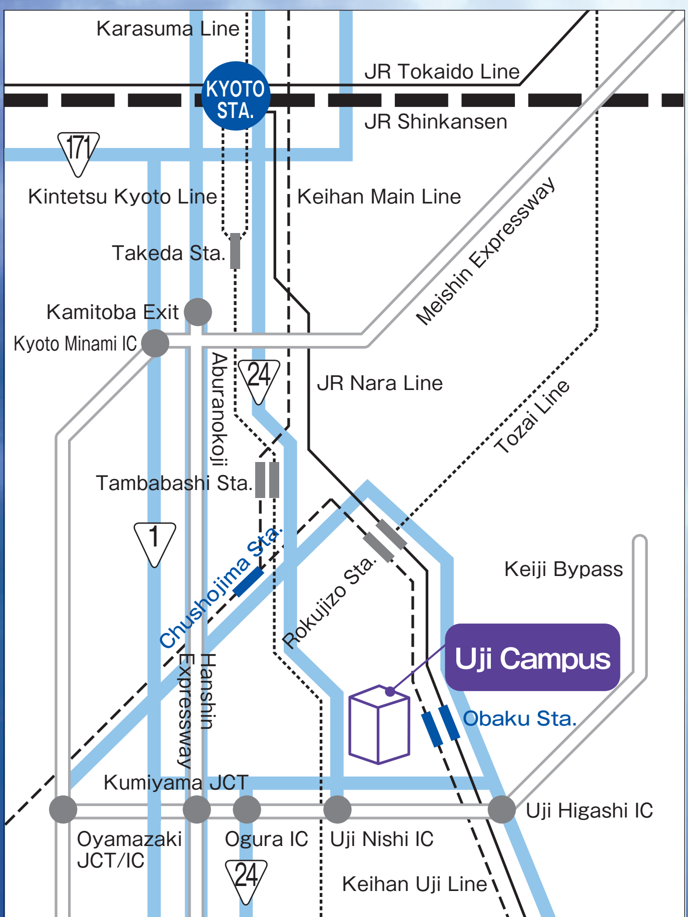


The number of applicants to the collaboration program of the Laboratory for Complex Energy Processes

Category	2017
A1: Division of International and Industrial Partnership	5
A2: Division of Plasma and Quantum Energy Research	10
A3: Division of Soft Energy Science Research	9
Total	24

The number of applicants to the collaboration program of Joint Usage/Research Center on Zero-Emission Energy

Category	2017
(A) Core research subject	36
(B) Research subject	52
(C) Facility usage	11
(D) Workshop	1
Total	100



▶ACCESS

❶ By JR Line

JR Kyoto Station → JR Obaku Station → Uji Campus

22min JR Nara Line Local / 7min Walk

❷ By Keihan Line

Keihan Chushojima Station → Keihan Obaku Station → Uji Campus

9min Uji Line Local / 10min Walk

▶INFORMATION

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