HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION, KEK

IMSS

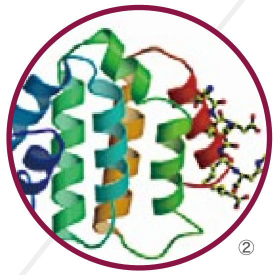
Institute of Materials Structure Science

Achievements of IMSS

The development of accelerators has allowed exploration into a new field of science, the "microscopic world." The structure and functionality of materials are closely linked to each other. In the recent years, the researchers have led to the evolution of electronic devices that are rapidly becoming smaller and more functional, and the drug design based on the structures of proteins. The Institute of Materials Structure Science (IMSS) effectively combines quantum beams (synchrotron radiation, neutron, muon and slow positron) to advance the frontiers of the microscopic world.

Analysis of Asteroid Particles

Chemical composition of the dust particles brought back by Hayabusa was studied by X-ray diffraction. Synchrotron radiation has illuminated the early history of the asteroid Itokawa and the solar system.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Protein Crystallography

Proteins are key molecules for all living matters. They have a structure of polymer chain of amino acids and functioned in a folded form. Synchrotron radiation has made rapid advances in the understanding of protein structures.


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The World-most Intense Pulsed Muons Beams

More than 70,000 muons per pulse were generated in December 2009. This allows us to conduct fundamental researches in physics, but also application researches that lead to improvement of our everyday life.


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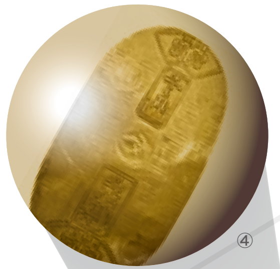
Medical Imaging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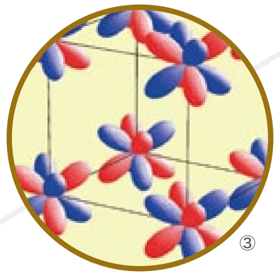
Non-destructive Multi-element Analysis

The archeological materials should be determined without damaging or destroying them. We used negatively charged muons for a non-destructive analysis of elements and found the depth profile of old coins.

High-Tc Superconductivity

Neutrons were used to define the structure of copper oxide superconductors. The relation between carrier doping and magnetism was understood using muons, and the electronic state was revealed by synchrotron radiation.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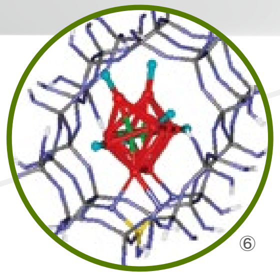
Novel Ordered State

It is a frontier of materials science to find new states and phases of materials. Orbital ordering of electrons has been found for the first time in the world.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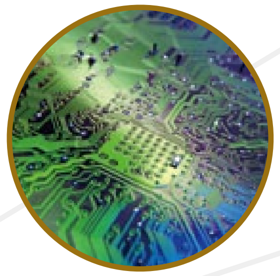
Catalyst

Catalysts, which increase the efficiency of chemical reactions, are indispensable in industries. Investigation into the structure of catalysts is an important foundation for the development of new catalysts.

Lithium-ion Battery・Fuel Cell

Neutrons and muons are powerful research tools to increase the capacity and lifetime of next-generation batteries. Neutrons are useful to identify light elements, and the positions of lithium in lithium-ion battery materials are revealed. Muons can replace hydrogen, and the motion of hydrogen in fuel cells is studied.



Nanotechnology

The electrons in nanometer scale show peculiar properties, and which should be understood to develop new materials and technologies.

IMSS
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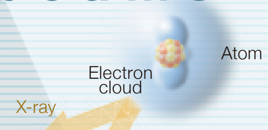
Exploring the microscopic world

Four beams

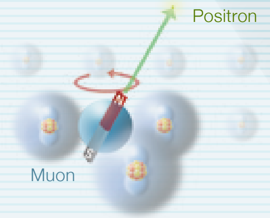


Synchrotron Radiation

Synchrotron radiation is a high- brilliant light with a wide range of energies (wavelengths) from an accelerator. Ultraviolet light and X-rays are used to investigate the configuration of atoms and the behavior of electrons in materials.

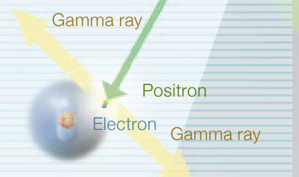
Neutron

Neutrons generated in a proton accelerator can identify nuclei. They are useful to observe the structure and motion of light elements, such as hydrogen and lithium. A part in interest is clearly detected by replacing with isotopes. Their permeability is very strong, and the structure inside materials can be investigated.



Muon

Muons are born as the decay product of pions which were generated by a proton accelerator. Muons are intrinsic magnets, acting as atom-sized compass which can be used to investigate the local magnetic fields in materials. Negatively charged muons are known to emit X-rays unique to each element, and they can be used to for element analysis.



Slow Positron

A positron is the antiparticle of an electron and is generated by an electron beam from a linear accelerator. Gamma rays, which are a result of the annihilation of a positron and an electron in a material, and positronium, which is a pair of an electron and a positron, are used to investigate the structure of materials.

Honorary Supreme Professor, KEK

Nobel Laureate in Chemistry, 2009

Prof. Ada Yonath

Prof. Yonath was awarded the Nobel Prize in Chemistry in 2009 "for studies of the structure and function of the ribosome". She started this work at the Photon Factory and developed a low-temperature crystal structure analysis method that has been used to study the structure of many proteins.

Prof. Ada Yonath : Dan Porgres

① X-ray Image of rat leg veins: The University of Tsukuba, NHK Science and Technology Research Laboratories
② Structure of the VHS domain of GGA1, a transporter protein
③ Antiferro-type state of magnetic octupoles in CeB_6: Takeshi Matsumura, Hiroshima University
④ "Tmpo Koban" Old Japanese coin: International Christian University, JAEA, National Museum of Japanese History
⑤ D1 equipment (μSR spectrometer)
⑥ Structure of rhenium catalyst for the best phenol synthesis: The University of Tokyo

Future of IMSS

Discovery of phenomena and their origins may ultimately help preserving life and the environment. IMSS is developing new accelerators, beams and detector technologies to step into unexplored territories such as extreme, ultrafast and ultrasmall world.

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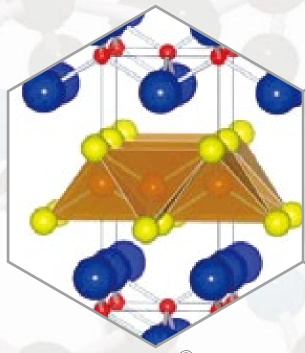
Earth and Planetary Science

Exploring the environment deep inside the Earth

The inside of the Earth is an extreme environment, with temperatures of a few thousand degrees and pressures of a few tens of thousands of atmospheres. Simulating such environments in experimental devices can reveal the mechanisms of changes in minerals inside the earth, including those that cause earthquakes and volcanic eruptions.

Analysis of extraterrestrial samples

The Universe contains substantial information on the history of the Earth and the Solar System. Precious samples, available in only small quantities, such as meteors from outer space and samples collected by spacecraft, are effectively investigated with high-brilliant beams and highly sensitive detectors.



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Materials Science

Spintronics: beyond electronics

The "giant magnetoresistance effect" that significantly advanced the reduction in size and increase in capacity of computer hard drives is a well-known phenomenon of "spintronics," which couples the electric and magnetic properties of materials. Many devices whose performances exceed those of traditional electronics devices will be commercialized. X-ray diffraction, X-ray absorption and ultra slow muons are being used to understand the origins of such peculiar properties and to observe spin dynamics, which will lead to the designs for new devices.

Soft matter that links materials and life

Soft matter, which is an aggregate of large, complex molecules, is used in a wide range of products from detergents and cosmetics to liquid crystal displays. Lipids and proteins that constitute living tissue are also soft matter. Neutrons and synchrotron X-rays are used to investigate not only the relation between the complex structure and functionality of soft matter, but also the relation between materials and life through biomimetic systems, for example, oil droplets that move around like amoebae.

Life Science

Membrane proteins: structure, function and drug design

Membrane proteins perform important biological activities to transfer materials and information into and out of a cell. They are also important as targets for drug design. Crystallization of membrane proteins is difficult and in many cases only a very small crystals are formed. Development of high-brilliant light source and higher sensitivity detectors allows the structural analysis of micro-crystals.

Capturing biological movements

Organisms move over a wide timescale, from motion that we can capture fast chemical reactions at the femtosecond. For example, photosynthetic reaction center proteins in leaves absorb light and transform its energy to chemical reactions in 100 femtoseconds. Synchrotron radiation, which is pulsed light, is an effective tool for capturing dynamics of biological movements.

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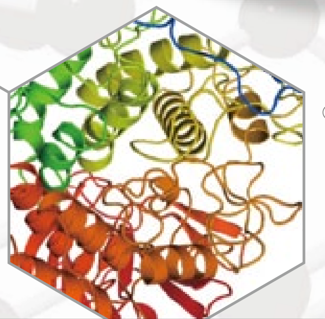
Energy and Environmental Science

CO_2-free energy

The clear energies attract considerable attentions. They do not emit CO_2 and not rely on fossil fuels and nuclear power. Our discoveries increase the efficiency of the functional materials such as solar cells, fuel cells and hydrogen storage alloys.

Making superconductivity practical

Practical use of superconductivity will fix the problems of power loss and heating due to electrical resistance, resulting in the saving of electricity. New superconducting materials such as copper oxides, iron-based systems and organic compounds have been discovered. There are, however, still issues to be solved to use superconducting materials in everyday life. Our quantum beams are used to perform research for the discovery of practical superconducting materials.



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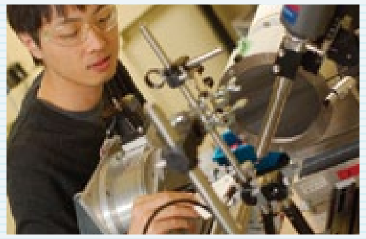
① Structure of AfcA fucosidase from *Bifidobacterium bifidum*　② Garnet　③ Crystal structure of an iron-based superconductor ($CaFe_{1-x}Co_xAsF$)
④ Hydrogen storage alloy ($LaNi_5$)　⑤ Moving oil drop (tetradecane): Yutaka Sumino, The University of Tokyo

Research use and education

● Inter-university research institute

KEK, to which IMSS belongs, is an inter-university research institute corporation. Large accelerators and related equipment at KEK, which are difficult for individual universities to maintain, can be used free of charge by universities and public research institutions both inside and outside Japan. IMSS accepts about 4,000 researchers per year who work in a wide variety of fields.

Contact : Research Cooperation Division, Research Collaboration and User Support Office
✉ **kyodo1@mail.kek.jp**



● Academic-industrial collaboration

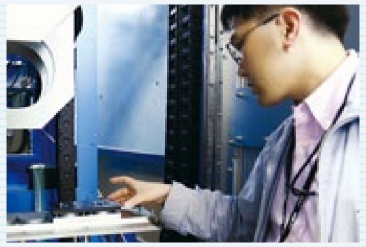
In the academic-industrial collaboration system, researchers from the industry and the IMSS staff work jointly on projects that have resulted in innovative achievements. Human resources, cost, and equipment are shared to provide close collaboration support by using the best resources from academia and the industry.

Contact : Research Cooperation Division, Cooperative Research and Development Office
✉ **kenkyo2@mail.kek.jp**

● Graduate education

KEK is one of a core institute of the Graduate University for Advanced Studies (Sokendai). IMSS carries out graduate education in the Department of Materials Structure Science, School of High Energy Accelerator Science. IMSS also accepts graduate students from universities all over Japan and the world to train them for the next generation.

Contact : Research Cooperation Division, Graduate Education Section
✉ **kyodo2@mail.kek.jp**



International collaboration

The operation of the Australian Beamline at the Photon Factory was started in 1992. It contributed to cutting-edge research conducted by Australian researchers and to the establishment of the Australian Synchrotron facility. The Indian Beamline was built in 2009, which allows fundamental research by Indian researchers. We have recently been working on synchrotron research collaboration in the Asia-Oceania region and have been contributing to the construction of the SESAME accelerator in the Middle East. The Japan-UK agreement from 1986 resulted in the construction of the neutron chopper spectrometer, MARI, at ISIS in the UK with long-term visits by researchers. This formed the foundation of neutron science technology for the construction of neutron spectrometers at J-PARC. IMSS sponsors exchanges of researchers conducting advanced experiments using muon beams as well as the collaborative development of experimental devices and analysis techniques with the Paul Scherrer Institute (PSI) in Switzerland and the Tri-University Meson Factory (TRIUMF) in Canada.

Experimental facilities

● Photon Factory (PF)

The Photon Factory has two light source accelerators. The PF ring (2.5 GeV) has been operated since 1982. This is the first dedicated synchrotron light source in Japan, which supply X-rays. Several improvements of accelerator have been made and resulted in high-brilliant light source. The PF-AR (advanced ring) is a unique light source, that is, high-intensity pulsed synchrotron source which is effective for time resolved experiments. There are 50 experimental stations at PF and PF-AR.

● Materials and Life Science Experimental Facility (MLF)

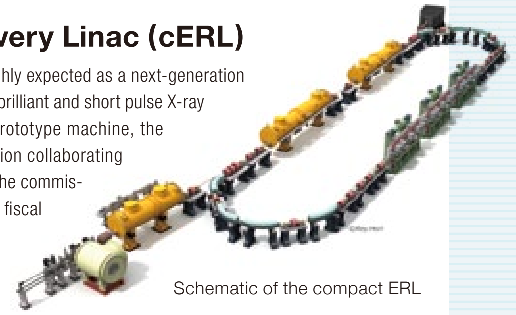
This research facility utilizes neutrons and muons generated by a high-intensity proton beam. IMSS has six neutron instruments and a muon spectrometer with the world's highest-intensity pulsed muon beam, which are provided for use by academia and the industry.

● Slow Positron Facility (SPF)

This is a facility to research the structure and functionality of materials using the slow positron beam generated by an electron beam from a linear accelerator (linac).

● Compact Energy Recovery Linac (cERL)

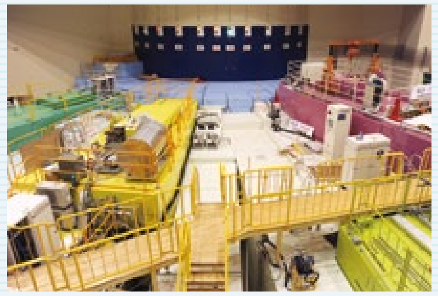
The energy recovery linac (ERL) at KEK is highly expected as a next-generation light source accelerator. It will provide a high-brilliant and short pulse X-ray that exceeds current radiation sources. A prototype machine, the compact ERL, is in the process of construction collaborating with researchers from Japan and overseas. The commissioning is scheduled to start in the end of the fiscal year 2012.


Schematic of the compact ERL


PF Ring (in front) and PF-AR (back)


PF Experimental Hall


MLF External View


MLF Experimental Hall

Organization

IMSS is a research organization that researchers from both inside and outside Japan study the structure and functionality of materials using accelerators. Its mission is to maintain experimental equipment and detector systems and to provide them to researchers based on their research objectives. Synchrotron radiation, neutrons, muons and slow positrons are used to comprehensively investigate a wide range of materials from those at the atomic level to polymers and biomolecules. IMSS has divisions for each research methodology and comprehensive research groups, that is, the Structural Biology Research Center, the Condensed Matter Research Center and the IMSS Detector System Development Team.

● Structural Biology Research Center

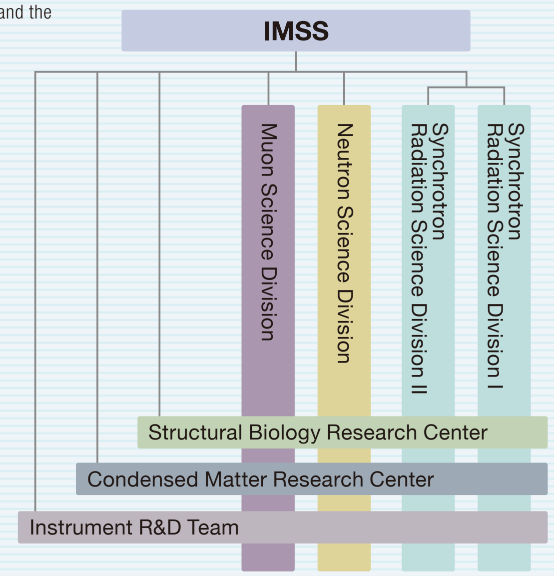
This center promotes research and development of not only molecular and cell biology but also the field of structural biology that includes development of devices for analysis. Other activities include development of technology to increase the efficiency of research. Examples are crystallization of proteins, which is necessary for the structural analysis of proteins; development of robots to exchange samples; and collaboration servers and software for integration.

● Condensed Matter Research Center

This center promotes research projects in fields important to materials science such as strongly correlated matter, surfaces and interfaces, soft matter, and materials in extreme environments through collaboration of researchers from inside and outside Japan. They explore new research areas across these fields.

● Instrument R&D Team

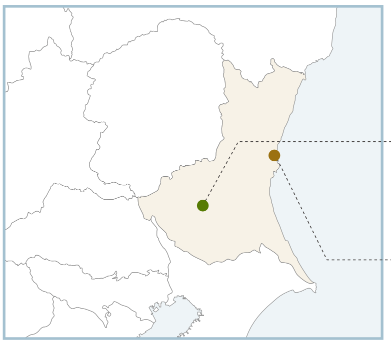
This team was established in April 2010 to coordinate and to promote detection technology research. They also function is to serve as an interface between many detector development teams inside and outside KEK and to always pursue the leading edge in detector technology.



Organization of IMSS

● Tsukuba Campus (KEK)
Photon Factory

● Tokai Campus (J-PARC)
Materials and Life Science Experimental Facility



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