The Department of Physics at Osaka University offers a world-class education to its undergraduate and graduate students. We have about 50 faculty members who teach physics to 76 undergraduate students per year in the Physics Department, and over 1000 students in other schools of the university. Our award-winning faculty members perform cutting edge research. As one of the leading universities in Japan, our mission is to serve the people of Japan and the world through education, research, and outreach.

The Department of Physics was established in 1931 when Osaka University was founded. The tradition of originality in research was established by the first president of Osaka University, Hantaro Nagaoka, a prominent physicist who proposed a planetary model for atoms before Rutherford’s splitting of the atom. Our former faculty include Hidetsugu Yagi, who invented the Yagi antenna, and Seishi Kikuchi, who demonstrated electron diffraction and also constructed the first cyclotron in Japan. Hideki Yukawa created his meson theory for nuclear forces when he was a lecturer at Osaka University, and later became the first Japanese Nobel laureate. Other prominent professors in recent years include Takeo Nagamiya and Junjiro Kanamori who established the theory of magnetism, and Ryoyu Uchiyama who developed gauge theory.

Since then, our department has expanded to cover a wide range of physics, including experimental and theoretical elementary particle and nuclear physics, condensed matter physics, theoretical quantum physics, and interdisciplinary physics. In 2010, the “International Physics Course (IPC)” was created to offer classes in English to students from abroad.

The department also has cooperating groups in five laboratories in the university. Many faculty and students in the department collaborate with other laboratories in Japan and abroad, such as KEK, J-PARC, RIKEN, SPring8, CERN, FNAL, TRIUMF, RAL, and PSI.

Graduate Program

The Department of Physics at Osaka University offers a two-year graduate course in physics leading to a Master of Science in Physics, and a three-year course in Physics leading to a Ph.D. degree.

The M.S. course provides advanced study and training in research in physics. A total of 68 students are enrolled each year. The course includes lectures and relevant practical work. Each student joins a research group to pursue a course of supervised research on an approved subject in physics. A Master of Science in Physics is awarded if a submitted thesis and its oral presentation pass the department’s criteria.

For the Ph.D. course each student joins a research group, and is assigned a research supervisor. Independent original research is central to the Ph.D. and successful graduates require a high degree of self-motivation. The final examination involves the submission of a Ph.D. thesis followed by an oral examination assessed by both internal and external examiners.

Graduates from the M.S. course either advance to the Ph.D. course or go to industry. Many graduates from the Ph.D. course become postdocs or assistant professors and continue their research. Graduates going to industry are highly valued for their understanding of physics, and their problem solving abilities.
Kobayashi Group

[Research Areas]
1) To clarify and control various quantum, many-body, and nonequilibrium effects in solid state devices.
2) Quantum Fluctuation Theorem, quantum measurement & quantum feedback control in solid state devices.
3) Electron- and nuclear- spin dependent transport.
4) Dynamics of electron transport in various materials (topological insulators, magnetic tunneling junctions, etc.)
5) Quantum effect induced by pulsed high magnetic fields.
6) Development of measurement techniques to address dynamical aspects of electron transport.

Recent progress in nanotechnology enables us to directly address quantum transport of electrons in nano-devices made of metal or semiconductor. For example, the wave nature of electrons can be controlled in electronic interferometers ("Aharonov-Bohm rings"), while their particle nature is accessible in quantum dots ("artificial atoms"). We can even combine these two kinds of devices into one, where the wave-particle duality in quantum mechanics manifests itself.

Hanasaki Group

[Research Subjects]
Novel magnetotransport phenomena and thermoelectric effect originating from the strong electron correlation in the organic and the inorganic conductors.

The strongly correlated electron systems provide a lot of interesting magnetotransport phenomena such as the giant magnetoresistance effect. For the realization of the giant magnetoresistance effect, the correlation between the spin and the charge degrees of the freedom is essential, since the spin configuration, which is controlled by the magnetic field, determines the electron transfer. The phthalocyanine molecules have the strong intramolecular interaction between the conduction electrons and the local moments. In this molecular conductors, we found the giant negative magnetoresistance. The thermoelectric effect is also investigated in the organic and inorganic conductors.
**Nozue Group**

**Members**
Yasuo NOZUE (Professor), Sadao TAKAOKA (Associate Professor),
Takehito NAKANO (Assistant Professor), Tsuyoshi TAKAMI (Assistant Professor),
Isao WATANABE (Guest Professor), Yasuhiro SAKAMOTO (Guest Associate Professor)

**Research Items**
1) Strongly correlated electron system in nanostructured materials
2) Synthesis of regular nanoclusters arrayed in nanospace of zeolites
3) Magnetic and other electronic properties of arrayed nanoclusters
4) MuSR study of condensed materials

**Research Contents**
We are studying arrayed nanoclusters stabilized in porous crystals of zeolites by a wide variety of measurements, such as wide range optical spectroscopy, magnetic measurement, electron spin resonance, MuSR, electric transport, etc. In zeolite crystals, such as A (Fig. 1) and X, nanocages with internal diameters of 11 and 13 Å are arrayed in simple cubic and diamond structures, respectively. By the loading of guest alkali metal into the nanocages, the s-electrons of alkali atoms are made to successively occupy 1s, 1p and 1d quantum electronic states of the clusters (Fig. 2). New electronic states like superatoms are formed. Novel electronic properties, such as ferromagnetism of s-electrons and metal-insulator transition are observed. These phenomena are explained by the mutual interaction of arrayed clusters, the orbital degeneracy, electron correlation, etc. Amazingly, ferromagnetic properties are found in non-magnetic elements introduced into the nanospace of zeolites crystals.

![Fig. 1](image1.png)
Schematic illustration of clusters arrayed in zeolite A crystals

![Fig. 2](image2.png)
Quantum states of electrons confined in nanocluster with the inside diameter of 11 Å

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**Toyoda Group**

**Members**
Michisato TOYODA (Professor), Morio ISHIHARA (Associate Professor),
Jun AOKI (Assistant Professor)

**Research Area**
1) Development of a novel mass spectrometer with ultra-high sensitivity and ultra-trace sampling for planetary exploration.
2) Development of a high-performance lightweight mass spectrometer for on-site analysis.
3) Development of a tandem time-of-flight (TOF) mass spectrometer suitable for proteome analysis.
4) Construction of ultra high resolution high speed imaging mass spectrometric technology (MS microscope).

The mass spectrometry is widely used in many fields, e.g., space science, biochemistry, physics and pharmacology. In order to study those fields, we develop high performance mass spectrometers such as multi-turn time-of-flight mass spectrometers.
**Tajima Group**

Setsuko TAJIMA (Professor), Shigeki MIYASAKA (Associate Professor), Masamichi NAKAJIMA (Assistant Professor), Alfred BARON (Guest Professor), Kiyohisa TANAKA (Guest Associate Professor)

[Research Area]

1) Studies on magnetic field-induced quantum phases and phase transitions
2) High magnetic field studies and quantum criticality of strongly correlated electron systems
3) High magnetic field studies of functional materials
4) Development of experimental apparatus utilized under multiplex extreme conditions.

Magnetic field is one of the important physical parameters such as pressure and temperature, and is a soft and precisely controllable external parameter. It interacts directly with spin degrees of freedom and orbital motions of electrons that characterize the nature of materials.

We are aiming at observing new phenomena in ultrahigh magnetic fields combined with other extreme conditions such as very high pressure and extremely low temperatures, and enlightening their mechanism. In order to conduct such researches, we are developing experimental apparatuses for investigating physical properties of e.g. high-Tc iron pnictide superconductors by elucidation not only of high temperature superconductivity mechanism but also of these new phenomena.

The discovery of high-Tc cuprates has explored new research on the strongly correlated electron systems. The strong electron correlation causes a variety of intriguing physical properties, such as high temperature superconductivity, Mott transition, colossal magnetoresistance and charge/orbital order. In order to find new exotic phenomena, we are investigating the charge dynamics in these systems.

**Hagiwara Group**

Masayuki HAGIWARA (Professor), Kiyohiro SUGIYAMA (Associate Professor), Takanori KIDA (Assistant Professor), Mitsuru AKAKI (Assistant Professor)

[Research Area]

1) Studies on magnetic field-induced quantum phases and phase transitions
2) High magnetic field studies and quantum criticality of strongly correlated electron systems
3) High magnetic field studies of functional materials
4) Development of experimental apparatus utilized under multiplex extreme conditions.

Magnetic field is one of the important physical parameters such as pressure and temperature, and is a soft and precisely controllable external parameter. It interacts directly with spin degrees of freedom and orbital motions of electrons that characterize the nature of materials.

We are aiming at observing new phenomena in ultrahigh magnetic fields combined with other extreme conditions such as very high pressure and extremely low temperatures, and enlightening their mechanism. In order to conduct such researches, we are developing experimental apparatuses for investigating physical properties of e.g. high-Tc iron pnictide superconductors by utilizing a huge capacitor bank system and a wide-bore pulse magnet as shown in the figures below. We have also developed electron spin resonance apparatuses with a very wide frequency-magnetic field window to study spin dynamics of novel magnets like quantum spin systems and/or frustrated magnets.
Kishimoto Group

**Members**
Tadafumi KISHIMOTO (Professor), Atsushi SAKAGUCHI (Associate Professor),
Sei YOSHI DA (Associate Professor)

**[Research Area]**
1) Study of Majorana mass of neutrino by double beta decay.
2) Search for Dark matters of our universe.
3) Kaon condensation in neutron stars.
4) Nuclear system with strangeness.

Recently it has been confirmed that three types of neutrino have different masses by oscillation experiments. However, mass itself has yet to be measured. Observation of double beta decay verifies that neutrino has Majorana mass which violates conservation of lepton number by nature. It thus tells us reason why our universe can be a world with only matters (no antimatters). These research can only be achieved at the low background circumstance for which underground laboratory is best suited. We constructed CANDLES detector at the Kamioka underground laboratory for the study. We also work on a search for dark matters which requires similar low background circumstance.

We are studying nuclear systems with strangeness. Observed mass of neutron stars are in a narrow range. It is considered to be due to the fact that the core of the neutron stars, which is a single giant nucleus, is a nuclear matter with strangeness. In order to have further understanding on the nature of the core, we are studying kaon nucleus interaction. Structure of hypernuclei, which we are intensively studying, gives similar information. Recently we are studying kaon nucleon interaction. It would give a solution to the recent problem on the penta-quark.

Shimoda Group

**Members**
Tadashi SHIMODA (Professor), Atsuko ODAHARA (Associate Professor),
Suguru SHIMIZU (Assistant Professor)

**[Research Area]**
1) Structure of nuclei far from the beta-stability line.
2) Structure of high-spin isomers (long-lived excited states).
3) Nuclear structures studied by laser spectroscopy in superfluid helium.

Recent experiments with state-of-the-art accelerators, radiation detector systems, lasers to control the quantum atomic states, and so forth have enabled us to explore the exotic nuclear structures with high sensitivity and high precision. We are concentrating on the following high-priority subjects. 1) Structures of very unstable nuclei with a large excess of proton numbers to those of neutrons, or vice versa: They show very different structures from those of nuclei in or close to the beta-stability line. We are investigating such structures by our unique method using spin-polarized unstable nuclei. 2) Structures of high-spin isomers which have extraordinary long lifetimes: From the systematic studies of the highly excited high-spin isomers, we found characteristic shapes of these isomers. We investigated the mechanism to achieve such structures and revealed the basic nucleon-nucleon interactions. We are searching for new isomers as a clue to yet undiscovered exotic deformed states. 3) Research and development of laser spectroscopy in superfluid helium. The interaction between the impurity atoms and helium may enable optical pumping, which has been hitherto impossible, for various atomic species. We succeeded in pumping Rb and Cs atoms in superfluid helium and found unexpectedly long spin-relaxation times. These results suggest efficient applications of the laser spectroscopy in superfluid helium for the measurements of electromagnetic moments of unstable nuclei.
Nuclear and Solid State Physics Group
[Kishimoto Group]

Members
- Kensaku MATSUTA (Associate Professor), Mitsunori FUKUDA (Associate Professor), Mototsugu MIHARA (Assistant Professor)

[Research Area]
1) Elucidation of structure of unstable nuclei through measurements of nuclear moments and reaction cross sections.
2) Dynamics of quarks and mesons in the nucleus.
3) Study of symmetries in nature through nuclear beta decays and ultracold neutrons (UCN).
4) Study of hyperfine interactions of nuclear probes and muons in materials with the NMR detected by beta-ray emission (beta-NMR and muon spin rotation).

We succeeded to detect quark- and meson-effects in the nucleus. These effects were found to relate strongly to the nuclear matter density. So, we are studying the structure of thin neutron- and proton-haloes spreading outside of the nucleus, to study the relation more precisely. For the study, we produce various unstable nuclei using our 5-MV van de Graaff accelerator in Osaka Univ., the cyclotron in RIKEN and the synchrotron in National Institute of Radiological Sciences, and measure reaction cross sections and nuclear moments applying beta-NMR technique. We explore the nuelson density distributions and shell structure through these measurements. Additionally, we study limitation of symmetries in the law of nature, which these phenomena are subject to, through nuclear beta decays. Further, we can measure magnetic fields and electric field gradients inside crystals by observing the beta-NMR on these unstable nuclear probes implanted directly in various kinds of substances. From these internal fields, we elucidate electron density and its band structure in the crystal. We are collaborating with TRIUMF (Canada) and CIAE (P.R. China) for these studies.

Kuno Group

Members
- Yoshitaka KUNO (Professor), Masaharu AOKI (Associate Professor), Akira SATO (Assistant Professor), Katsuhiro ISHIDA (Visiting Professor)

[Research Area]
1) Study of lepton flavor violation by searching for muon-to-electron conversion processes in a muonic atom.
2) Study of lepton universality by precise measurements of the rare pion decay process.
3) Development of a next-generation muon source with the highest intensity, the highest luminosity and the highest purity in the world.
4) Development of a method of ionization cooling for neutrino factory R&D, where a neutrino factory is a highly intense neutrino source based on decays of muons in a muon storage ring.
5) Study of a high intensity muon beam source “MUSIC” at RCNP, Osaka University.
6) Study of neutrinos with Super-Kamiokande

To answer fundamental questions such as “What is the origin of the Universe?”, there are two different experimental approaches in particle physics. One is the high-energy frontier approach and the other is the high-intensity frontier approach. The Kuno group adopts the latter, the high-intensity approach, and aims to obtain experimental evidences to reveal new physics scheme beyond the current Standard Model of particle physics. In particular, the Kuno group is looking for the processes that are forbidden in the Standard Model (such process as lepton flavor violation, like a muon-to-electron conversion) or making precise measurements of the processes that are allowed in the Standard Model (such as the lepton universality, and the matter-antimatter asymmetry in neutrinos). Furthermore, to accomplish such research goals, it is necessary to develop novel and unique experimental methods and detection methods, which are based on advanced technologies. For this purpose, we are, for instance, developing on a next-generation muon source with the highest-intensity, the highest-luminosity and the highest-purity in the world, which is called “PRISM”, and a future neutrino facility called a “neutrino factory”. We are also aiming to make applications of these technologies to other interdisciplinary fields, and also technology transfer and spin-off to industry.
[Research Area]
1) Study of Higgs particle and search for Super Symmetric particles.

Right after the Big Bang, the same number of particles and antiparticles were produced, but they annihilated each other into photons as the universe cooled down. However, there are matters (such as stars) left in this universe. This was caused by a small unbalance of $O(10^{-9})$ between the behaviors of particles and antiparticles; so called CP violation. Such CP violation must have been caused by new physics beyond the standard model. At a new high interisity proton accelerator, J-PARC, we are studying a rare CP-violating K decay to look for new physics beyond the standard model.

In addition, right after the Big Bang, all the particles were massless. However, they obtained mass due to Higgs particle. Using the highest energy proton-proton collider at CERN, we are studying the Higgs particle. The same collider will allow us to produce undiscovered particles predicted by Supersymmetry which is the most popular theory beyond the Standard Model. We are also searching for such supersymmetric particles.

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Hadrons are particles that interact with strong force. Protons and neutrons that constitute nuclei are hadrons. So are Yukawa mesons. These particles were considered as elementary particles, but it is now known that they are composed of quarks and gluons, which are more fundamental particles. Two types of hadrons have been known, mesons and baryons. Mesons are made of two (anti)quarks and baryons are made of three (anti)quarks. Recently, the possibility of other types of hadrons has been considered. Isolated quarks or gluons cannot exist in the world where we live now, but it is believed that quarks and gluons are deconfined and can move freely at high temperature, above approximately $2 \times 10^{12}$ K. Such high temperature once existed in early universe. We are trying to understand such diverse dynamics in the world of the strong interaction, played by quarks, gluons, and hadrons.
Particle Physics Theory Group  
**[Hosotani Group]**

**Members**  
Yutaka HOSOTANI (Professor), Kin-ya ODA (Associate Professor),  
Yoichi NAMBU (Distinguished Honorary Professor),  
Wade NAYLOR (Associate Professor, Concurrent position), Eiichi TAKASUGI (Guest Professor)

**[Research Area]**  
1) Unified theory of elementary particles and interactions  
2) Origin of matter (quarks and leptons)  
3) Cosmology, dark matter and blackholes  
4) Hosotani mechanism  
5) Foundation of quantum field theory and string theory

What are the most fundamental building blocks of matter? What is the origin of quarks and leptons? How do they interact with each other? How are all the interactions unified? How was the universe born? How has it evolved to the present? These are the questions we are going to answer.

The biggest mysteries in current physics are the Higgs boson and dark matter. A Higgs-like boson was found at LHC in 2012. Yet we do not know its true character. The issue is to pin down the structure of the unification of forces. There may be supersymmetry and extra-dimensional space behind them.

The ultimate unification of all interactions including gravity becomes possible in superstring theory. We are entering a new era in which the notion of spacetime is revolutionized.

Particle Physics Theory Group  
**[Onogi Group]**

**Members**  
Tetsuya ONOGI (Professor), Minoru TANAKA (Assistant Professor),  
Hidenori FUKAYA (Assistant Professor)

**[Research Area]**  
1) Lattice QCD and its application to particle physics and field theory  
2) Origin of flavor mixing and CP violation  
3) Mechanism for electroweak symmetry breaking and the properties of the Higgs bosons

**[Research Contents]**  
1. Nonperturbative study of field theories from lattice - Dynamics of gauge theories (electroweak phase transition, walking technicolor), electroweak matrix element from lattice QCD.  
2. CP violation in B, D, K mesons  
3. Higgs Boson and Supersymmetric Model Phenomenology - properties of Higgs bosons, Higgs boson hunting in accelerator experiments
Particle Physics Theory Group
[Hashimoto Group]

Members
Koji HASHIMOTO (Professor), Satoshi YAMAGUCHI (Associate Professor), Norihiro IIZUKA (Assistant Professor)

Quantum field theory is the most advanced formulation of physics we have ever reached. Two basic principles of modern physics, relativity and quantum theory, are incorporated in it. The gravity theory of Einstein however is not incorporated in this framework. The most promising candidate is the superstring theory. We are pursuing fundamental problems of particle physics by examining various possibilities of the quantum field theory and the superstring theory. Furthermore, we apply mathematical tools developed in string theory and quantum field theories to various physical phenomena, which would connect different subjects of science via mathematical physics.

Kubota Group
(Center for Education in Liberal Arts and Sciences)

Members
Takahiro KUBOTA (Professor)

Home Page
http://www.dma.jim.osaka-u.ac.jp/view?l=ja&u=2300

[Research Interests]
1. Holographic relations between supersymmetric gauge theories and gravity
2. Applications of field theory technics to cosmology
3. Search for new sources of CP-violation
4. Properties of Higgs bosons and neutrinos

[Introduction to the research interests]
One of the most important problems in particle physics is to construct a unified description of all interactions including gravity. For this purpose it has been expected that the AdS/CFT correspondence would play a key role. We have been much involved in studying holographic properties between gravity and gauge theories.

We are also very much interested in the early universe and have been applying particle physics technics to computation of cosmological correlation functions. We are also concerned with the baryon number production in early universe, and in particular with new sources of CP-violation. We are analyzing electric dipole moments of neutron and various atoms by using R-parity violating supersymmetric models to search for new origins of CP-violation.

In connection with the on-going accelerator experiments, the precision test based on radiative corrections is our most favorite subject. We have been interested in the allowed regions of masses of charged and CP-odd Higgs bosons which are expected to be discovered soon.
Kuroki Group

**Members**

Kazuhiko KUROI (Professor), Keith SLEVIN (Associate Professor),
Yoshifumi SAKAMOTO (Assistant Professor), Masako OGURA (Assistant Professor)

1) Electron correlation effects, unconventional superconductivity
2) Optimization of thermoelectric effects
3) First principles electronic structure calculation and materials design, including the investigation of the mechanisms underlying various electronic, magnetic, optical, and mechanical properties of condensed matter.
4) Quantum transport phenomena in disordered systems, Anderson localization
5) Structure and phase transition on solid surfaces

The cooperation between the band structure and the electron correlation effects can give rise to various phenomena such as superconductivity and magnetism, but correctly understanding the correlation effect is in general difficult and therefore a challenging issue. In addition to the above, the presence of impurities, defects and randomness in solids can also lead to interesting phenomena such as the Anderson localization. We investigate these issues numerically and/or analytically, and are also interested in developing new theoretical methods to analyze these problems.

Ogawa Group

**Members**

Tetsuo OGAWA (Professor), Kenichi ASANO (Associate Professor),
Takuma OHASHI (Assistant Professor), Yasuhiro AKUTSU (Professor)

**Research Area**

1) Low-dimensional many-body quantum systems.
2) Photoinduced quantum phase transitions: the exciton Mott transition.
3) Optically-excited states and their dynamical responses.
4) Quantum theory of lasing in correlated electron-hole systems.
5) Control of quantum states of light.
6) Development of numerical schemes for computational statistical mechanics.

"Hard" materials: magnetic matters, electronic systems, dielectric materials, solid-state surfaces, and "soft" materials: high polymers, proteins, molecular crystals, and so on.

We are interested in solids, which are composed of many microscopic components, e.g., atoms and molecules. Such materials exhibit dramatic and interesting phenomena, phase transitions and/or nonlinear responses, due to interactions among their constituents. There remain many not yet understood phenomena that will require highly-sophisticated theoretical treatments beyond one-body approximations. Our group is trying to explain these exotic phenomena using analytical and computational techniques. We cover many target materials, i.e.,
**Department of Physics**

**Fundamental Nuclear Physics Group**  
*(Research Center for Nuclear Physics · Toyonaka Laboratory)*

*Members*  
Masaharu NOMACHI (Professor), Yoshitaka FUJITA (Associate Professor),  
Noriyoshi ISHII (Associate Professor), Hiroyuki KAMANO (Specially Appointed Assistant Professor),  
Takayasu SEKIHARA (Postdoc Fellow), Kosho MINOMO (Postdoc Fellow),  
Junko YAMAGATA-SEKIHARA (Postdoc Fellow), Hideko NAGAHIRO (Guest Researcher/Nara Women’s University),  
Takayuki MYO (Guest Researcher/Osaka Institute of Technology)

**[Research Area]**  
1) Neutrino physics (Double beta decay experiment).  
2) Search for Higgs (ATLAS experiment).  
3) Advanced radiation detector development to explore physics frontiers.  
4) Nuclear structure (Isospin symmetry in nuclear physics).

The origin of matter and the origin of mass is fundamental questions in physics.  
One of the keys to understand the problems is the study of the neutrino mass and its origin. We are studying the neutrino mass by the double beta decay experiment. We are developing advanced radiation detectors to explore those physics frontiers. Nuclear structures are studied through Isospin symmetry.

**Quark Nuclear Physics Theory Group**  
*(Research Center for Nuclear Physics)*

*Members*  
Atsushi HOSAKA (Professor), Kazuyuki OGATA (Associate Professor),  
Noriyoshi ISHII (Associate Professor), Hiroyuki KAMANO (Specially Appointed Assistant Professor),  
Takayasu SEKIHARA (Postdoc Fellow), Kosho MINOMO (Postdoc Fellow),  
Junko YAMAGATA-SEKIHARA (Postdoc Fellow), Hideko NAGAHIRO (Guest Researcher/Nara Women’s University),  
Takayuki MYO (Guest Researcher/Osaka Institute of Technology)

**[Research Subjects]**  
Our study covers theoretical hadron and nuclear physics:  
1) Structure of hadrons (protons and neutrons) from quarks and gluons  
2) Lattice QCD study for hadron structure and interactions  
3) High precision reaction study for nuclear structure and synthesis  
4) Nuclear physics from QCD

Our aim is to understand the divers phenomena of strong interactions from quarks, baryons and nuclei to astrophysics phenomena. Quarks are confined and the vacuum breaks chiral symmetry, but we do not know how quarks form nucleons. Yukawa's interaction by the pion binds the nucleus, but we still cannot solve fully the nuclear-many-body problems. It is rather recent that we can describe nuclear reactions microscopically for the study of history of the universe. We are approaching these problems by using various methods of theoretical physics of quantum mechanics, relativity and field theory. Our method also uses the world top supercomputer Kei. In performing our research, we discuss and collaborate with many physicists from the world. We also discuss with experimentalists who are working at the RCNP cyclotron, SPring-8, KEK, RIKEN and J-PARC.
Particle and Nuclear Reactions IA Group
(Research Center for Nuclear Physics)

Members
Nori AOI (Professor), Atsushi TAMII (Associate Professor),
Eiji IDEGUCHI (Associate Professor), Tatsushi SHIMA (Assistant Professor),
Keiji TAKAHISA (Assistant Professor), Tomokazu SUZUKI (Assistant Professor),

[Research Area]
1) Spin and isospin responses of nuclei and giant resonances
2) Deformation and vibration of nuclei
3) α-cluster structure and its appearance mechanism
4) Carbon synthesis in the universe
5) Tensor interaction in nuclei originating from Yukawa pion
6) Structure and reaction of unstable nuclei
7) De-coupling of proton and neutron distribution in stable and unstable nuclei

A nucleus is a quantum many-body system consisting of protons and neutrons, which are interacting each other with strong force. Nuclear structures have been investigated with many kinds of probes and it has been realized that a nucleus is a quite unique system, where independent particle motions and collective motions coexist. To understand the nature of nuclei, it becomes more important to clarify microscopic structures produced by nucleons near the surface, to search various collective motions with large amplitudes and to investigate modifications of nucleon properties in the nuclear medium.

Nuclear physics is important in interdisciplinary fields such as astrophysics, engineering and medical application. We study nuclear interactions and structures with 0.01-0.4 GeV/nucleon beams obtained by the RCNP cyclotron. This energy region is most adequate to study nuclear medium and spin isospin responses. The nucleon motions associated with spins and isospins are interesting from several points of view. Spin isospin interactions give rise to spin isospin giant resonances. The spin isospin responses are associated with pi- and rho-meson exchange interactions. Nuclear spin isospin interactions are relevant to axial-vector weak responses in nuclei. They are crucial for studies of nuclear responses to neutrinos.

With high quality beams and high performance detectors, these physics programs are under way, in collaboration with many physicists from all over the world.

Particle and Nuclear Reactions IB Group
(Research Center for Nuclear Physics)

Members
Takashi NAKANO (Professor), Hiroyuki NOUMI (Professor),
Masaru YOSOI (Professor), Shuhei AJIMURA (Associate Professor),
Hiroaki OHNISHI (Specially Appointed Associate Professor),
Tomoaki HOTTA (Assistant Professor), Kotaro SHIROTORI (Assistant Professor),
Atsushi TOKIYASU (Specially Appointed Assistant Professor),

[Research Theme]
1) Study of the Quark-Nuclear Physics through the meson- and baryon- photoproductions to understand the hadrons in terms of the quarks and their interactions.
2) Search for the exotic particles such as penta-quarks.
3) Construction and operation of the high-energy polarized photon beam facility by laser-backscattering from the 8 GeV electron beam.
4) Development of the detector system for the precise measurement of photo-nuclear reactions with protons and nuclei in the GeV energy region.
5) Development of the HD polarized target.
6) Spectroscopic study of charmed baryons with a high-momentum pion beam and Quark-Nuclear Physics with K and other hadron beams at J-PARC (Tokai).

Since the wave-length of a few GeV gamma-ray is less than the size of a hadron, typically a proton (~1 fm), it becomes possible to investigate its sub-structure, i.e., the world of quarks and gluons with GeV photons. A polarized GeV-photon beam with good qualities is produced by the backward-Compton scattering of laser photons from high energy electrons. Our group studies the interactions and structures of hadrons in terms of the quarks and their interactions, which is called the Quark-Nuclear Physics. The experiment is performed at SPring-8 which is the synchrotron radiation ring with the highest energy (8 GeV) in the world. Experimental studies of the Quark-Nuclear Physics with high intensity hadron beams at J-PARC are being developed.

Our group has found an evidence for an exotic baryon with an anti-strange quark (penta-quark ‘Theta’) for the first time. Making sure of its existence and revealing its structure are two of the main goals. The investigations of the quark confinement, quark-pair (diquark) correlations, the partial restoration of the chiral symmetry in the nuclear medium, the freedom of quarks and gluons in the nuclear force, etc. are other objectives. The experimental study is being done with state-of-the-art technologies in order to understand the physical material from the quark-gluon level, also expecting the encounter with unknown phenomena.
**Accelerator Physics Group**

(Research Center for Nuclear Physics)

**Members**
Kichiji HATANAKA (Professor), Mitsuhiro FUKUDA (Professor),
Tetsuhiro YORITA (Assistant Professor), Hiroshi UEDA (Specially Appointed Assistant Professor)

**[Research Area]**
1) Upgrading of the ring and AVF cyclotrons to provide ultra high-quality beams for precision nuclear physics experiments.
2) Ion source developments for production of high-brightness and high-intensity ion beams.
3) R&D of a future GeV particle accelerator.
4) R&D of next-generation accelerators and their applications utilizing new technologies like high-temperature superconducting (HTS) magnet.

The RCNP cyclotron facility, consisting of a K400 ring cyclotron and a K140 AVF cyclotron, plays an important role in nuclear physics using intermediate-energy nuclear beams. We study accelerator and beam physics for upgrading the high-performance cyclotrons and ion sources to provide ultra high-quality beams for precision nuclear physics experiments. The R&D of a new particle accelerator to produce ultra-precise GeV beams is in progress for pioneering research fields in particle and nuclear physics. The R&D for applications of state-of-art accelerator technologies to medical, biological, materials sciences and industry is under way; for example, development of high-temperature superconducting magnets for the particle cancer therapy.

![A photograph of the ring cyclotron](image)

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**Quantum System Electronics Group**

(The Institute of Scientific and Industrial Research)

**Members**
Akira OIWA (Professor), Shigehiko HASEGAWA (Associate Professor),
Shuichi EMURA (Assistant Professor)

**[Research Areas]**
1) Spin-related quantum transport and nano-level characterization in semiconductor low dimensional systems
2) Quantum interface between single photon and single spin and its application to quantum information processing
3) Novel magnetic semiconductors and their semiconductor spintronics device applications.
4) Wide band-gap semiconductor based materials integration and their device applications.

Quantum system electronics group studies novel optical, electronic, and spin devices that support the highly-sophisticated information society in the 21st century. Based on semiconductor devices, our research fields are quantum information processing using the quantum mechanical nature of electron spins and photons, and spintronics based on the development and hybridization of optical, electrical and spin materials. We study the growth and characterization of high quality materials and perform precise quantum transport measurements. Aim of our research is the realization of novel phenomena emerging in quantum nano-structures that can control the photon, electron and spin degrees of freedom.

![Molecular beam epitaxy](image)
Isoyama Group
(The Institute of Scientific and Industrial Research)

**Members**
Goro ISOYAMA (Professor), Ryukou KATO (Associate Professor),
Akinori IRIZAWA (Assistant Professor), Keigo KAWASE (Assistant Professor)

**[Research Area]**
1) Study on production of a high-brightness electron beam with a linear accelerator.
2) Development of an infrared free electron laser.
3) Basic study for X-ray lasers by means of Self-Amplified Spontaneous Emission (SASE).
4) Application study of the high power THz radiation.

Particle accelerators are widely used in various fields from basic sciences such as high energy physics and nuclear physics to industrial applications. Among them, we conduct researches on electron accelerators and related subjects. There are three electron linear accelerators at the Institute of Scientific and Industrial Research and we make use of one of them to conduct research on production of a high-quality electron beam and on generation and application of a new light beam called the quantum beam. Our research activities extend from basic physical processes to development of high-performance accelerators and study on solid state physics using the high-intensity THz radiation. The photograph shows a far-infrared free electron laser, which can generate a high-intensity laser beam in the wavelength region between light and the electromagnetic wave. The red device is a part of the free electron laser called the wiggler, which wiggles the high energy electron beam to emit light. The electron linac is located behind the wiggler.

Oguchi Group
(The Institute of Scientific and Industrial Research)

**Members**
Tamio OGUCHI (Professor), Koun SHIRAI (Associate Professor),
Kunihiko YAMAUCHI (Assistant Professor), Hiroyoshi MOMIDA (Assistant Professor),
Mitsuhiro MOTOKAWA (Guest Professor), Takeo JO (Guest Professor)

**[Research Area]**
1) Novel electronic properties associated with broken symmetry
2) Materials design based on the prediction of phase stability
3) Cross correlation effects between multi-orders in multiferroics
4) Development of first-principles methods

Various materials such as metals, semiconductors, oxides, and organics can be characterized by their physical and chemical properties, such as electronic conductivity, optical properties, and chemical reactivity, which exhibit variations over wide ranges. In order to utilize those properties in our life, it is desirable to produce materials with preferable properties by modifying their microscopic structures. To this end, it is of crucial importance to clarify the mechanisms underlying their physical and chemical properties. We are developing computational techniques based on quantum mechanics (first-principles methods). The forefront methods are applied to real materials to study their properties, and even to hypothetical structures to design new materials. Based on the obtained knowledge, we extract ideas to design new materials with desired properties. We are collaborating with experimental groups to prove our predictions. Through our researches, we wish to contribute to our society in terms of researches of clean and efficient energy resources, environmental protection, and development of industries.
Kimura Group
(Graduate School of Frontier Biosciences)

Members
Shin-ichi KIMURA (Professor), Junji WATANABE (Associate Professor),
Shinya YOSHIOKA (Assistant Professor), Yoshiyuki OHTSUBO (Assistant Professor)

[Research Area]
3. Order and pattern formation processes in nonequilibrium systems.

Physical properties of solids, such as magnetism and superconducting, and life phenomena, such as redox and photosynthesis, originate from the electronic states in materials and their interactions. To clarify the electronic states provides us not only the information of the origins of the physical properties and life phenomena but also the expectation and creation of novel functionalities. To visualize of the change of the electronic state, we develop new spectroscopic techniques using synchrotron radiation and other quantum beams. The photograph is the symmetry- and momentum-resolved electronic structure analysis instrument (SAMRAI) developed at UVSOR, the high-brilliance low-energy synchrotron radiation facility.

In thermally nonequilibrium systems, various structural and functional orders come out simultaneously. We perform experiments to clarify these phenomena in various systems such as laser oscillation, vibrational reaction, colloidal crystal, domain formation and living systems.

Interdisciplinary Computational Physics Group
(Cybermedia Center)

Members
Macoto KIKUCHI (Professor), Hajime YOSHINO (Associate Professor)

[Research Area]
1) Protein foldings, design and evolution.
2) Traffic flows as nonlinear dynamical systems.
3) Mechanism of biomolecular motor.
4) Critical phenomena and phase transition.
5) New Monte Carlo sampling methods based on extended ensembles.

Various interdisciplinary subjects, e.g., biological systems and traffic flows, are studied in the light of statistical mechanics, nonlinear dynamics and computational physics. Although the subjects seem to be quite different from each other, at first glance, they share the same key concepts: their complex behaviors emerged from the complex interactions among large number of relatively simple elements. Studying them in the uniform view point, we can make each particular case clear all the more. Researches on new methodologies of scientific computing are also in progress using a PC cluster system with more than 100 CPUs.
Intense Laser Science Group

(Institute of Laser Engineering)

Members  Hiroshi AZECHI (Professor), Keisuke SHIGEMORI (Associate Professor)

[Research Area]
1) Laser Fusion.
2) Radiation Hydrodynamics, High-Density Plasma Physics.
3) Precision Diagnostics Development.

The ultimate goal of our activity is to realize laser fusion as a next generation energy source by creating plasmas with one thousand times solid density and a temperature of one hundred million degree Kelvin. On the way towards this goal, we study radiation hydrodynamics and high-density plasma physics (Fermi degeneracy and strongly coupled plasma) as physics basis of laser fusion. We also study unexplored physics by using a peta (ten to the fifteenth)-watt laser.