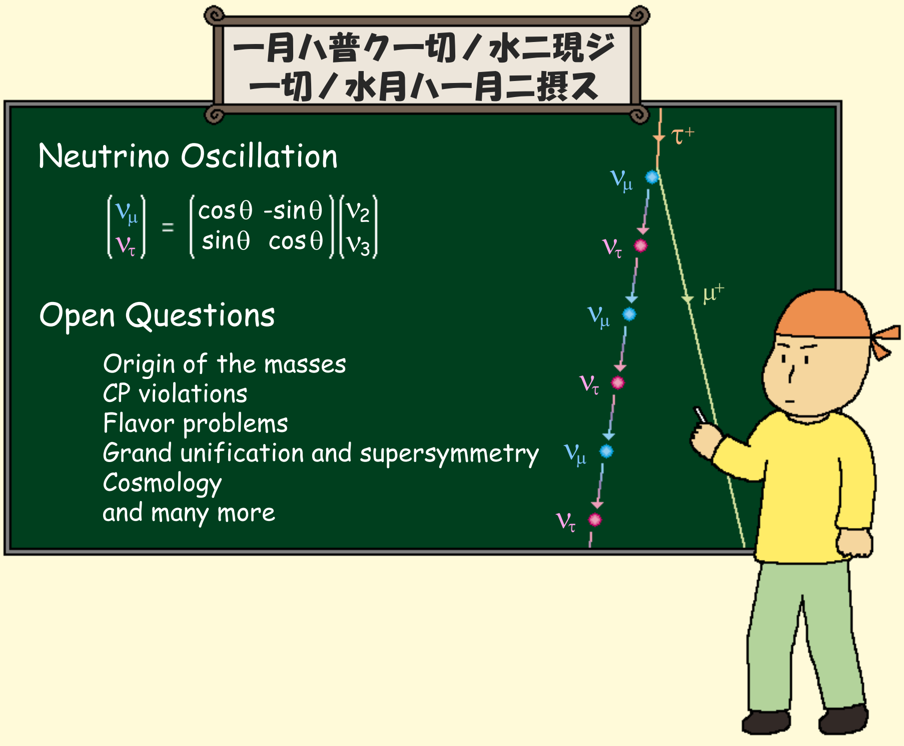
Guide to Graduate School
Department of Physics
Tohoku University



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cover

Neutrino Oscillation

In 2002, KamLAND group, which has been promoted by Tohoku University, succeeded in observing a deficit of neutrino flux generated by nuclear power plants. The result strongly suggests neutrino oscillation phenomenon which is beyond the standard model of elementary particle physics. It has also been placing a great impact on the studies of neutrinos which are deeply related to fundamental questions, such as the origin of mass, CP violation, flavor physics, super-symmetry and so on.

Welcome to Department of Physics, Tohoku University

This pamphlet outlines interest and activity of all the research groups in Department of Physics, Tohoku University for those young people who intend to study physics seriously in the graduate course. Our Department of Physics is one of the largest in Japan. The advanced research here covers wide areas of modern physics from particle and nuclear physics to condensed matter physics and biophysics. Actively involved in the graduate school programs are not only the faculty members of our Department of Physics, but also members of research institutes and laboratories associated with Tohoku University.

In our Department, graduate students often contribute to research gaining international recognition in areas ranging from basic to most current subjects, under the guidance of their supervisors. Our Department boasts well equipped research facilities which are utilized by a wide variety of researchers as well as graduate students, and which support the high level of the research. We expect that enrolled students, who are willing to play a leading role in physics of the next generation with pioneering spirit, develop further their ability and originality through education in our Department.

For more detailed information, we suggest visiting our webpage, written partly in Japanese.

http://www.phys.tohoku.ac.jp/

Research Groups and Members

Particle and Nuclear Theory

(i) Theoretical Nuclear and Particle Physics (Department of Physics)

Research Group	Title	Name		Page
Particle Theory	Professor	Zyun F. Ezawa	江澤 潤一	7
	Professor	Ken-ichi Hikasa	日笠 健一	
	Professor	Masahiro Yamaguchi	山口 昌弘	
	Associate Professor	Takeo Moroi	諸井 健夫	
	Associate Professor	Masaharu Tanabashi	棚橋 誠治	
	Associate Professor	Satoshi Watamura	綿村 哲	
	Assistant Professor	Masahiro Hotta	堀田 昌寛	
	Assistant Professor	Hiroshi Ishikawa	石川 洋	
	Assistant Professor	Yukinari Sumino	隅野 行成	
	Assistant Professor	Youichi Yamada	山田 洋一	
Nuclear Theory	Professor	Noboru Takigawa	滝川 昇	8
	Associate Professor	Kouichi Hagino	萩野 浩一	
	Assistant Professor	Masahiro Maruyama	丸山 政弘	
	Assistant Professor	Akira Ono	小野 章	

Condensed Matter Theory

(i) Theoretical Condensed Matter Physics (Department of Physics)

Research Group	Title	Name		Page
Theoretical Condensed Matter and Statistical Physics	Professor	Toshihiro Kawakatsu	川勝 年洋	9
	Professor	Yoshio Kuramoto	倉本 義夫	
	Professor	Riichiro Saito	齋藤 理一郎	
	Professor	Komajiro Niizeki	新関 駒二郎	
	Associate Professor	Sumio Ishihara	石原 純夫	
	Associate Professor	Toru Sakai	坂井 徹	
	Associate Professor	Yoshinori Hayakawa	早川 美徳	
	Assistant Professor	Tsuyoshi Hondou	本堂 毅	
	Assistant Professor	Wataru Izumida	泉田 渉	
	Assistant Professor	Hiroaki Kusunose	楠瀬 博明	
	Assistant Professor	Munehisa Matsumoto	松本 宗久	
	Assistant Professor	Tatsuya Nakajima	中島 龍也	
	Assistant Professor	Nariya Uchida	内田 就也	
	Assistant Professor	Hisatoshi Yokoyama	横山 寿敏	

(ii) Metal Physics (Institute for Materials Research)

Research Group	Title	Name		Page
Quantum Condensed Matter Theory	Professor	Sadamichi Maekawa	前川 禎通	10
	Associate Professor	Takami Tohyama	遠山 貴巳	
	Assistant Professor	Tomio Koyama	小山 富男	
	Assistant Professor	Saburo Takahashi	高橋 三郎	
	Assistant Professor	Wataru Koshibae	小椎八重 航	
Quantum Transport Theory	Professor	Hidetoshi Fukuyama	福山 秀敏	10

Experimental Nuclear and Particle Physics

(i) Experimental Nuclear and Particle Physics, High Energy Physics
(Department of Physics and Research Center for Neutrino Science)

Research Group	Title	Name		Page
Experimental Particle Physics	Professor	Atsuto Suzuki	鈴木 厚人	11
	Professor	Akira Yamaguchi	山口 晃	
	Professor	Hitoshi Yamamoto	山本 均	
	Associate Professor	Junpei Shirai	白井 淳平	
	Associate Professor	Fumihiko Suekane	末包 文彦	
	Associate Professor	Kunio Inoue	井上 邦雄	
	Associate Professor	Tomoki Hayashino	林野 友紀	
	Assistant Professor	Tadashi Nagamine	長嶺 忠	
	Assistant Professor	Takuya Hasegawa	長谷川 琢哉	
	Assistant Professor	Masayuki Koga	古賀 真之	
Experimental Nuclear Physics	Professor	Osamu Hashimoto	橋本 治	12
	Professor	Toshio Kobayashi	小林 俊雄	
	Associate Professor	Hirokazu Tamura	田村 裕和	
	Associate Professor	Naohito Iwasa	岩佐 直仁	
	Associate Professor	Satoshi N. Nakamura	中村 哲	
	Assistant Professor	Yuu Fujii	藤井 優	
	Assistant Professor	Hideaki Otsu	大津 秀暁	
Intermediate Energy Nuclear Physics	Professor	Haruhisa Miyase	宮瀬 晴久	13
	Associate Professor	Kazushige Maeda	前田 和茂	
	Assistant Professor	Hiroki Kanda	神田 浩樹	

(ii) Nuclear Science (Laboratory of Nuclear Science)

Research Group	Title	Name		Page
Nuclear Science	Professor	Jirohta Kasagi	笠木 治郎太	14
	Professor	Hajime Shimizu	清水 肇	
	Professor	Hiroyuki Hama	浜 広幸	
	Associate Professor	Tadaaki Tamae	玉江 忠明	
	Associate Professor	Tsutomu Ohtsuki	大槻 勤	
	Associate Professor	Masayuki Kawai	河合 正之	
	Assistant Professor	Hirohito Yamazaki	山崎 寛仁	
	Assistant Professor	Fujio Hinode	日出 富士雄	
	Assistant Professor	Katsuhiro Shinto	神藤 勝啓	
	Assistant Professor	Hideyuki Yuki	結城 秀行	

(iii) Nuclear Radiation Physics (Cyclotron and Radioisotope Center)

Research Group	Title	Name		Page
Nuclear Radiation Physics	Professor	Hiroyuki Okamura	岡村 弘之	15
	Associate Professor	Tsutomu Shinozuka	篠塚 勉	
	Assistant Professor	Atsuki Terakawa	寺川 貴樹	
	Assistant Professor	Masahiro Fujita	藤田 正広	

(iv) Accelerator Science (Japan Atomic Energy Research Institute)

Research Group	Title	Name		Page
Accelerator Science	Guest Professor	Hideaki Yokomizo	横溝 英明	15
	Guest Professor	Shoji Nagamiya	永宮 正治	
	Guest Associate Professor	Osamu Sasaki	佐々木 修	

Condensed Matter Experiment I

(i) Condensed Matter Physics -Electronic Properties- (Department of Physics)
Strongly Interacting Many Particle Quantum Systems
(Very Low Temperature Physics Division - Center for Low Temperature Science)

Research Group	Title	Name		Page
Microscopic Research on Magnetism	Professor	Hideya Onodera	小野寺 秀也	17
	Associate Professor	Shigeru Takagi	高木 滋	
	Assistant Professor	Aya Toubou	東方 綾	
Materials Structure Physics	Professor	Youichi Murakami	村上 洋一	17
	Associate Professor	Kazuaki Iwasa	岩佐 和晃	
	Assistant Professor	Takeshi Matsumura	松村 武	
	Assistant Professor	Hironori Nakao	中尾 裕則	
Low-Dimensional Quantum Physics	Professor	Naoki Toyota	豊田 直樹	18
	Associate Professor	Hiroshi Matsui	松井 広志	
Photoemission Solid State Physics	Professor	Takashi Takahashi	高橋 隆	18
	Assistant Professor	Takafumi Sato	佐藤 宇史	
Solid State Physics on Nano-Network Solids	Professor	Katsumi Tanigaki	谷垣 勝己	19
Very Low Temperature Physics - Center for Low Temperature Science	Professor	Haruyoshi Aoki	青木 晴善	19
	Associate Professor	Akira Ochiai	落合 明	
	Assistant Professor	Noriaki Kimura	木村 憲彰	

(ii) Metal Physics (Institute for Materials Research and Low Temperature Science Division - Center for Low Temperature Science)

Research Group	Title	Name		Page
Superconductivity Physics	Professor	Norio Kobayashi	小林 典男	20
	Associate Professor	Takahiko Sasaki	佐々木 孝彦	
	Assistant Professor	Terukazu Nishizaki	西嵜 照和	
	Assistant Professor	Naoki Yoneyama	米山 直樹	
	Assistant Professor	Kazutaka Kudo	工藤 一貴	
Metallic Magnetism	Professor	Kazuyoshi Yamada	山田 和芳	20
	Associate Professor	Kenji Ohoyama	大山 研司	
	Assistant Professor	Masaki Fujita	藤田 全基	
	Assistant Professor	Haruhiro Hiraka	平賀 晴弘	
Nanostructured Materials	Professor	Yoshihiro Iwasa	岩佐 義宏	21
	Associate Professor	Yasujiro Taguchi	田口 康二郎	
	Assistant Professor	Taishi Takenobu	竹延 大志	
	Assistant Professor	Shin-ichiro Kobayashi	小林慎一郎	
High magnetic field Condensed Matter	Professor	Hiroyuki Nojiri	野尻 浩之	
	Assistant Professor	Iwao Mogi	茂木 巖	
Low Temperature Material Science - Center for Low Temperature Science	Associate Professor	Tsutomu Nojima	野島 勉	21
	Assistant Professor	Shintaro Nakamura	中村 慎太郎	

(iii) Physics of Actinide Group (Japan Atomic Energy Research Institute)

Research Group	Title	Name		Page
Actinide Physics	Guest Professor	Jun'ichiro Mizuki	水木 純一郎	22
	Guest Associate Professor	Naoto Metoki	目時 直人	
	Guest Associate Professor	Yasuji Muramatsu	村松 康司	

Condensed Matter Experiment II

(i) Quantum Condensed Matter Physics, Biophysics (Department of Physics)

Research Group	Title	Name		Page
Synchrotron Radiation and Photoelectron	Associate Professor	Shoji Suzuki	鈴木 章二	22
Surface Physics	Professor	Shozo Suto	須藤 彰三	23
	Assistant Professor	Kazuyuki Sakamoto	坂本 一之	
Laser Spectroscopy	Professor	Seishiro Saikan	齋官 清四郎	23
	Associate Professor	Masayuki Yoshizawa	吉澤 雅幸	
	Assistant Professor	Akitoshi Koreeda	是枝 聡肇	
Biophysics	Professor	Kazuo Ohki	大木 和夫	24
	Associate Professor	Hidetake Miyata	宮田 英威	
	Assistant Professor	Tetsuhiko Ohba	大場 哲彦	
Solid State Photophysics	Professor	Teruya Ishihara	石原 照也	24
	Associate Professor	Shinichiro Iwai	岩井 伸一郎	
	Assistant Professor	Masanobu Iwanaga	岩長 祐伸	

(ii) Crystal Physics (Institute for Materials Research)

Research Group	Title	Name		Page
Lattice Defect Physics	Associate Professor	Ichiro Yonenaga	米永 一郎	25
Crystal Growth Physics	Professor	Kazuo Nakajima	中嶋 一雄	25
	Associate Professor	Noritaka Usami	宇佐見 徳隆	
	Lecturer	Gen Sazaki	佐崎 元	
	Assistant Professor	Kozo Fujiwara	藤原 航三	
Surface/Interface Science	Professor	Toshio Sakurai	櫻井 利夫	26
	Associate Professor	Tadaaki Nagao	長尾 忠昭	
	Assistant Professor	Yasunori Fujikawa	藤川 安仁	
	Assistant Professor	Jerzy T. Sadowski		
	Assistant Professor	Yukiko Yamada-Takamura	高村（山田）由起子	

(iii) Solid State Spectroscopy (Institute of Multidisciplinary Research for Advanced Materials)

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Solid State Ion Physics	Professor	Jun'ichi Kawamura	河村 純一	26
	Associate Professor	Yukio Shibata	柴田 行男	
	Assistant Professor	Osamu Kamishima	神嶋 修	
Correlated-electron Solid State Physics	Professor	Taka-hisa Arima	有馬 孝尚	27
	Assistant Professor	Kimihiro Ishi	伊師 君弘	
Electron -Crystallography and -Spectroscopy	Professor	Masami Terauchi	寺内 正己	27
	Associate Professor	Kenji Tsuda	津田 健治	
Structural Physics and Crystal Physics	Professor	Yukio Noda	野田 幸男	28
	Assistant Professor	Masashi Watanabe	渡邉 真史	
	Assistant Professor	Hiroyuki Kimura	木村 宏之	

(iv) Laser Quantum Optics (The Institute of Physical and Chemical Research)

Research Group	Title	Name		Page
Laser Quantum Optics	Guest Professor	Yusaburo Segawa	瀬川 勇三郎	28
	Guest Associate Professor	Bao-ping Zhang	張 保平	
	Guest Associate Professor	Kodo Kawase	川瀬 晃道	

Particle Theory Group

Professor	:	Zyun F. Ezawa, Ken-ichi Hikasa and Masahiro Yamaguchi
Associate Professor	:	Takeo Moroi, Masaharu Tanabashi and Satoshi Watamura
Assistant Professor	:	Masahiro Hotta, Hiroshi Ishikawa, Yukinari Sumino and Youichi Yamada

(http://www.tuhep.phys.tohoku.ac.jp/)

The subjects of *particle physics* are the elementary particles — the most basic constituents of matter — and their interactions — the most fundamental law of Nature. Particle physics is also called *high energy physics*, since the short-distance physics corresponds to the high-energy physics because of the uncertainty principle in quantum mechanics.

The theory of particle physics is based on relativistic quantum field theory. In particular, gauge theories are most important. Four interactions are known presently to act among particles: They are the electromagnetic interaction, the weak interaction, the strong interaction and the gravitational interaction. The first three interactions are merged into a single gauge theory, the **Standard Model**, which is surely one of the most important achievements in physics of the last century.

Although the standard model is very successful, it leaves many unanswered questions. Various candidates for physics beyond the standard model have been introduced to solve them. **Supersymmetry** and **Grand Unification** have received much attention in this context. There might exist new strong interactions such as technicolor. We study various aspects of these "physics beyond the standard model", e.g., unification of the coupling constants, proton decay, production of supersymmetric particles at colliders, neutrino mass, solar neutrinos, W boson scattering, CP violation and flavor-changing neutral current, etc..

Particle physics is intimately related to **cosmology**. Many kinds of particles, inaccessible in laboratory, must have played essential roles in the beginning of the universe. The present structure of the universe might be a result of interactions among many unknown particles activated by a high temperature at that time. We study cosmic dark matter, cosmology of gravitinos, inflation model of the universe, and the origin of the baryon number in the universe.

Gravity is described by general relativity as a classical theory. However, its quantization is an important problem yet to be solved. **Quantum gravity** will be essential in understanding the very early universe, the evaporation of black holes and so on. We study the singularity structure and topology of the space-time under strong gravitation. This is related to the problem of information loss in the quantum theory of black holes.

It is tempting to unify gravity as well. **Superstring theory** is a good candidate to unify all interactions. Recently there are big developments in this theory. We study string duality, Dirichlet membranes, Dirichlet instantons, F theory, and M theory.

Since quantum field theory is the basic tool in particle theory, we are very much interested in every aspect of quantum field theory. It is worthwhile to investigate it and develop it by its own sake. We are attempting to construct a new quantum field theory based on noncommutative geometry. It is also important to apply it to various branches of physics. For instance, **condensed matter physics** is a good field to test it. There is a good chance to gain entirely new insights from a quantum-field-theoretical point of view. Indeed, we have already obtained very new results by applying it to the analysis of quantum Hall effects.

In this way we are investigating various topics of *particle physics*, *cosmology* and *quantum field theory* widely from the ultimate microscope to the ultimate macroscope.

Nuclear Theory Group

Professor	:	Noboru Takigawa
Associate Professor	:	Kouichi Hagino
Assistant Professor	:	Masahiro Maruyama, Akira Ono

(http://www.nucl.phys.tohoku.ac.jp/)

Nuclei and hadrons are quantum many-body systems made of finite number of nucleons and mesons which are also composite particles consisting of quarks and gluons. They are self-bound by the strong interaction. Although the strong interaction is known to be described by the quantum chromodynamics (QCD), even the dynamics of a single hadron has not been fully understood because of its strong non-perturbative nature in the low energy region. One of the challenging and interesting subjects in theoretical nuclear physics is to explore non-perturbative properties of strongly-interacting systems. Since the first-principle calculation is extremely difficult, number of models and/or approximations are used based on relativistic/non-relativistic quantum mechanics and quantum field theories. A variety of pioneering works related to nuclear and hadronic phenomena from low to high energies are being carried out in this group. Present major activities cover heavy-ion reactions, nuclear fusion/fission, astrophysical nuclear reactions, liquid-gas nuclear phase transitions, nuclei under high temperature/density, structure and reactions of unstable nuclei, high-spin states, superdeformed bands, superheavy elements, quark-gluon plasma, color superconductivity, color confinement, QCD phase transition.

Theoretical Condensed Matter and Statistical Physics Group

Professor	:	Toshihiro Kawakatsu, Yoshio Kuramoto, Riichiro Saito, and Komajiro Niizeki
Associate Professor	:	Sumio Ishihara, Toru Sakai and Yoshinori Hayakawa
Assistant Professor	:	Nariya Uchida, Hiroaki Kusunose, Tatsuya Nakajima, Wataru Izumida Tsuyoshi Hondou Munehisa Matsumoto and Hisatoshi Yokoyama, (http://www.cmpt.phys.tohoku.ac.jp/)

The condensed matter theory group covers a large area of solid state physics and statistical physics, based on two fundamental frameworks; quantum mechanics and statistical mechanics. Exotic, new and fundamental properties are of interest in highly correlated systems, soft materials, nano-materials, quasi-crystal and so on. In addition to analytical approach, we perform numerical calculations for non-equilibrium systems or for electronic systems using sophisticated techniques. Domestic and international collaborations with experimental groups or industries stimulate our activities significantly. Every member of this large group is available for discussions on a daily basis, thereby helping student to understand the many aspects of current physics.

The following lists the research subjects for each group member. Further details can be found from the Web, or direct contact with group members can be made by e-mail.

Kawakatsu: Theory and simulation on the mesoscopic structures and their dynamics of soft materials such as polymers and surfactants.

Kuramoto: Magnetism and superconductivity in strongly correlated quantum systems, fractional statistics and supersymmetry in low-dimensional systems.

Saito: Solid state properties of carbon nanotubes, semiconductor physics, electronic structure calculations.

Niizeki: Structures and electronic states of quasicrystals; renormalization group, fractal geometry and computer simulation.

Hayakawa: Theory of fractal pattern growth and collective dynamics of neural networks under learning. Large scale computer simulations of granular/fluid systems.

Ishihara: Theory of correlated electron systems; spin-charge-orbital coupled quantum-liquid in oxides, colossal magnetic, electric and optical responses.

Sakai: Statistical theory of quantum spin and strongly correlated electron systems like high-T_c superconductors.

Hondou: Statistical physics and thermodynamics of small systems: thermal energy conversions, equations of state etc.

Izumida Quantum effects in nano-systems. Transport properties, electron correlation in quantum dot, carbon nanotube and nano-electromechanical systems.

Kusunose: Theory of magnetism and superconductivity in correlated electron systems with orbital degrees of freedom.

Matsumoto: Quantum phase transitions of quasi-one-dimensional quantum spin systems studied by the quantum Monte Carlo method, together with the development of new algorithms, especially interested in the effects of quantum fluctuations and dimensionality.

Nakajima: Theory of low dimensional systems; quantum Hall effect, Bose-Einstein condensation in dilute bose gas.

Uchida: Soft condensed matter, esp. pattern formation, nonlocal interaction and dynamics of phase transition in complex fluids.

Yokoyama: Strongly correlated electron systems, especially on high temperature superconductivity, itinerant magnetism and low-dimensional spin systems.

Quantum Condensed Matter Theory Group

Professor	:	Sadamichi Maekawa
Associate Professor	:	Takami Tohyama
Assistant Professor	:	Tomio Koyama, Saburo Takahashi and Wataru Koshibae

(http://www.maekawa-lab.imr.tohoku.ac.jp/)

The microscopic world such as atoms and molecules is governed by quantum mechanics which is a different law from that in the macroscopic world. This law sometimes appears in front of us when materials are selected and/or microfabrication technique is utilized to them. Superconductivity which appears in cuprates, metals and alloys is a typical example. Anomalous change of the electrical resistance caused by the magnetism in transition metal oxides and magnetic nanostructures is another one. The aim of this laboratory is to study theoretically quantum phenomena in materials.

The current research interests are:

1. The mechanism of superconductivity in cuprates and new superconducting materials with unique properties.

2. The metal-insulator transition and related anomalous phenomena in transition metal oxides.

3. The interplay of magnetism and transport properties in magnetic nanostructures.

By combining various theoretical methods and numerical ones with supercomputers, the above subjects are studied in collaboration with experimental groups.

Quantum Transport Theory Group

Professor : Hidetoshi Fukuyama

Properties of materials around us are truly diverse but the unifying understandings of these are possible by the theory of condensed matter physics based on quantum mechanics. This branch of science, which is founded on solid basis, is healthy as a natural science since it is always motivated by various types of experiments, and will further expand its research targets into the interdisciplinary fields between chemistry and biology. Among many properties, the transport properties of condensed matter reflect very subtle features of the quantum effects, which is the research target of this group. More explicitly,

1. Exploration of diversities and systematics of molecular solids
   – Charge ordering, and magnetic and superconducting phase transitions
2. Metal-Insulator transition in transition metal oxides
   – Phase transition of strongly correlated systems with disorder, i.e. Mott transition and Anderson transition.
3. Dielectric properties in disordered spin-Peierls systems
   – Disorder-induced antiferromagnetic long range order and dielectric anomalies
4. Persistent currents in finite systems
   – Magnetization of superconducting proximity systems and orbital magnetism in nanoscopic systems
5. Electrical conductivity of DNA
   – Possible carrier doping into molecular solids

* No plan to accept graduate students for the academic year of 2004.

Experimental Particle Physics Group

Professor	:	Atsuto Suzuki, Akira Yamaguchi and Hitoshi Yamamoto
Associate Professor	:	Junpei Shirai, Fumihiko Suekane, Kunio Inoue and Tomoki Hayashino
Assistant Professor	:	Tadashi Nagamine, Takuya Hasegawa and Masayuki Koga

(http://www.awa.tohoku.ac.jp/)

Non-Accelerator Experiments

Exploring the ultimate structure of matter, the fundamental principles of nature and the birth, evolution and death of the universe is an inevitable practice, which is imposed on the human beings. In order to study these subjects, experimental approaches in particle physics tend to pioneer the two different research fields with the opposite side energy. One is the ultra-high energy side, which is realized by high-energy particle accelerators. The other is the ultra-low energy side, where large volume and high sensitive particle detectors are equipped in a deep underground. In particular large volume underground detectors give opportunities for exploring the most important unsolved subjects on particle physics, astrophysics and cosmology.

The KamLAND project of Tohoku University was launched in 1997 with main objectives of (1) measurement of the neutrino masses and mixings through a search for neutrino oscillations of antineutrinos from faraway nuclear power reactors, (2) observation of ^{7}Be and ^{8}B solar neutrinos in order to understand an evolution of main sequence stars, (3) the first observation of geoneutrinos, and (4) study of relic and burst neutrinos from supernova explosions.

The construction was finished in the year 2001 and the data taking started from January 2002. The striking first results, ”evidence of reactor anti-neutrino disappearance,” has been announced in the end of 2002. It solves the long-standing (more than 30 years) solar neutrino problem. The data also indicated an excess of geo-neutrino events. KamLAND will pin-points neutrino oscillation parameters and starts a new field of ”Neutrino Geophysics” in coming years. And ”Neutrino Astrophysics” with an observation of low energy solar neutrinos will be accomplished by on-going big efforts.

Quasar/galaxy surveys to search for large scale structures of the universe such as the great wall, voids, super clusters at high red shifts are proceeding with Subaru telescope and Kiso Schmidt telescope.

Accelerator-based Experiment

Collisions of accelerated particles such as electrons and positrons make it possible to produce heavy particles such as B mesons and Z^0 bosons in the cleanest state. Observation of their production and decay is quite important to understand basic properties of elementary particles.

The BELLE experiment at KEK is an e^+e^- colliding experiment to study CP violation (asymmetry of the matter and anti-matter) in B particle, which is expected to be large in the standard model with Kobayashi-Masukawa scheme. The Tohoku group has joined the project and constructed resistive plate counters as a detector of K_L. The beam collisions in the accelerator KEKB, and data taking with the BELLE detector started in June 1999. The results from the BELLE experiment have led to new discoveries of CP violation in B meson decays.

Experimental Nuclear Physics Group

Professor	:	Osamu Hashimoto and Toshio Kobayashi
Associate Professor	:	Hirokazu Tamura, Naohito Iwasa and Satoshi Nakamura
Assistant Professor	:	Yuu Fujii and Hideaki Otsu

(http://lambda.phys.tohoku.ac.jp/)

Our group is experimentally investigating new types of nuclei in extreme conditions, **hypernuclei** and **proton/neutron-rich nuclei**. Hypernuclei are composed of hyperons (=baryons having "strangeness" quantum number) such as Λ and Σ particles in addition to protons and neutrons. Proton/neutron-rich nuclei are unstable nuclei having a large asymmetry in the proton/neutron numbers. We utilize accelerator facilities around the world use various beams of π/K mesons, electrons, and radioisotope nuclei. We are also designing experiments and developing apparatus for the J-PARC 50 GeV PS (proton synchrotron) in Tokai and the Radio Isotope Beam Factory at RIKEN, which will be available in near future.

1. Hypernuclear Physics

The goal of hypernuclear physics (or "strangeness nuclear physics") is the fundamental understanding of many-body hadron systems from the quark level through strangeness. We can explore deeply inner regions of nuclei with a hyperon which is free from Pauli principle. In addition, various modification of nuclear structure induced by a hyperon often explodes our common knowledge in nuclear physics. Structure of hypernuclei enables us to study hyperon-nucleon interactions, which extend our knowledge on nuclear force toward unified understanding of baryon-baryon interactions. The weak interaction between baryons can also be investigated through weak decays of hypernuclei.

Our group is one of the major research groups for strangeness nuclear physics in the world. We are carrying out pioneering and unique experimental studies. (1) Recently, we succeeded in high-resolution Λ hypernuclear spectroscopy by the $(e, e'K^+)$ reaction for the first time at Jefferson Lab in U.S. We are now constructing the High-resolution Kaon Spectrometer (HKS), with which improved experiments will start in 2005. (2) We are studying structure and weak decays of Λ hypernuclei using π meson beams and the Superconducting Kaon Spectrometer (SKS) at KEK-PS. (3) We recently constructed a large germanium detector array (Hyperball) and measured hypernuclear γ rays for the first time. With this new method, precise structures of various Λ hypernuclei are being studied at KEK-PS and Brookhaven Lab in U.S. (4) In order to study mechanism of strangeness production in electromagnetic interaction, we are investigating K^0 production by GeV γ-ray beams at Laboratory of Nuclear Science in Tohoku University.

2. Exotic Nuclear Physics with RI Beams

Another extreme form of nuclei is found at the extreme neutron/proton ratio. Those nuclei are far from the stability line and located near the neutron(proton) drip line. Unlike many stable nuclei the main features of such exotic nuclei are governed by the small number of active nucleons. Interesting phenomena are observed such as neutron halos (skins), soft giant dipole resonances, changes of the magic numbers, etc. Recently, it has become possible not only to produce such nuclei but also to use them as high-intensity high-purity secondary nuclear beams (RI beams). The group conducts experiments of those exotic nuclei using the accelerator facilities at RIKEN and National Institute of Radiological Sciences. We study (1) nuclear radius from reaction cross sections, (2) single particle states by nucleon knockout reactions, (3) resonance states just outside of the drip lines, (4) giant resonances by forward inelastic scattering of proton, and (5) nucleosysthesis from cross sections of nuclear reactions important inside stars.

Intermediate Energy Nuclear Physics Group

Professors : Haruhisa Miyase and Hiroaki Tsubota*
Associate Professor : Kazushige Maeda
Assistant Professor : Hiroki Kanda
(http://nuclear.phys.tohoku.ac.jp/)

Intermediate Energy Nuclear Physics group studies atomic nuclei by use of electron and photon beams. Electrons and photons are clean tools to study nuclear structure, since the interaction is weak, and is well understood by the established quantum electro dynamics. Our interests extend over many aspects in nuclear physics. In order to study them, we also use hadron probes in a wide energy range.

Collectivity of Nuclei

When a nucleus is irradiated by a few tens MeV photons whose wavelength is comparable to the nuclear size, a collective motion, for example, the giant resonance, is excited. The characteristics of the resonance, such as peak energies, widths and decay modes, are rich source to investigate the nuclear structure. We study the giant resonance by detecting decayed particles, such as photons, protons and neutrons, with modern technique.

Mesons and Nucleons in Nuclei

We can investigate nucleons inside the nucleus by using high-energy photons whose wavelengths are smaller than the nuclear size. By detecting several nucleons in coincidence, we can probe how they are interacting in the nucleus. In a photon energy of a few hundreds MeV, various mesons are also photo-produced in the nucleus. We can study the meson-nucleus interaction, and various nucleon resonances, since mesons strongly couple to the nucleon resonance.

Quark Nuclear Physics

A further step using much higher energy photons, whose wavelength is short enough to probe inside the nucleon, might be taken to investigate the nucleon structure. Bremsstrahrung γ beam with high duty factor (up to 70%) is now used for the photoproduction of K^0 and π mesons on nucleon. We have been developing the liquid deuterium cryostat for a neutron target. The exciting researches are planned to be carried out using completely polarized GeV photon beams.

Hyperon-Nucleon Interaction

The hyperon-nucleon scattering is studied for understanding of the interaction between hyperon and nucleon. The scintillating fiber active target with IIT readout was developed. It works both as the target for hyperon production through $(\pi^{\pm}, K^{+})$ reaction and as the proton target for elastic scattering of hyperons. The momentum region for $\Sigma^{\pm}$ and Λ is from 300 MeV/c to 1000 MeV/c.The first result for Σ^{-}-p elastic scattering was reported and further analyses for $\Sigma^{\pm}$-p and Λ-p elastic scattering are in progress.

Nuclear Science Group

Professor	:	Jirohta Kasagi, Hajime Shimizu and Hiroyuki Hama
Associate Professor	:	Tadaaki Tamae, Tsutomu Ohtsuki and Masayuki Kawai
Assistant Professor	:	Hirohito Yamazaki, Fujio Hinode, Katsuhiro Shinto, and Hideyuki Yuki

(http://www.lns.tohoku.ac.jp/)

The Laboratory of Nuclear Science (LNS) is a university-based laboratory affiliated to Graduate School of Science, Tohoku University. It was founded to aim at carrying out fundamental researches and applications in nuclear science as well as at educating students and researchers. The LNS facility operates two accelerators: a 300 MeV electron linear accelerator (LINAC) and a 1.2 GeV Stretcher-Booster ring (STB ring). The LINAC provides an intense pulsed beam and has been used in a wide range of research fields, not only in nuclear physics but in solid state physics, radiochemistry, biology, engineering, and so on. The construction of the STB ring of about 50 m in circumference was recently completed and the low-energy continuous beam became available for experiments. The 1.2 GeV electron beam started operation for experiments in 1999. Thus LNS provides tagged photon beams as well as continuous electron beams from 0.2 to 1.2 GeV in addition to the pulsed electron beams up to 0.25 GeV. The research program of Nuclear Science Group at LNS has three main components: the quark nuclear physics program, the accelerator science program, and the radiochemistry program as follows.

Quark Nuclear Physics

Diverse studies on the hadron structure in nuclei and on various motions of nucleons in nuclei have been going on using the GeV electrons and photons from the STB ring.

1. Hadrons in Nuclei: It is one of the most important things to do in QCD to search for precursors of the chiral transition which is expected to happen in high temperature and/or high density. The material density in the inside of the nucleus is extraordinarily high and is $\sim 10^{14} g/cm^3$. In this regards, the character change of hadrons in the nucleus has been investigated using a GeV photon beam, which is able to produce hadrons inside the nucleus.

2. Nuclear Physics: The nucleon-nucleon correlation, relativistic effects and meson exchange currents are investigated by observing particles emitted in electro- and photo-reactions. On the other hand, quantum tunneling phenomena, dynamics of alpha-decay and ultra-low energy nuclear reactions, have been studied as non-accelerator experiments.

Beam Physics/Accelerator Science

Non-linear beam dynamics in circular accelerators is studied by using the STB ring operated at the storage ring mode. Slow beam extraction results from stochastic excitation of the betatron oscillation by applying white noise perturbation has been theoretically and experimentally examined. In addition, fundamental accelerator physics for generation of very low beam emittance is progressed in collaboration with SPring-8. Furthermore production of a low emittance beam using an RF gun for a high brilliant coherent light source such as the free electron laser is also studied.

Radio-chemistry

Photo-nuclear reactions have been studied and applied to micro analysis of various elements in the environment and in biological material. Recently, a method to produce a radioactive fullerene (C_{60}) has been developed by bombarding fullerenes with electrons and charged particles. The production mechanism is being investigated in detail.

Nuclear Radiation Physics Group

Professor	:	Hiroyuki Okamura
Associate Professor	:	Tsutomu Shinozuka
Assistant Professor	:	Atsuki Terakawa, Masahiro Fujita

(http://www.cyric.tohoku.ac.jp/)

The nuclear radiation physics group consists of the accelerator research and instrumentation research divisions of the Cyclotron and Radioisotope Center (CYRIC) founded for multi-purpose use of a cyclotron and for handling of high-level radioisotopes. Construction of the new AVF cyclotron with K=130 MeV has been carried out in 1998 school years. In 1999 school year, the beam transport system and experimental facilities such as fast-neutron time-of-flight system, isotope separator equipped with Ge-ball gamma-ray detector, CsI high-energy gamma-ray detector system, etc. have been constructed. Our group studies the characteristic behaviors of nuclei, e.g., nuclear structure and interactions.

Projects in progress at the accelerator research division are; (1) development of the ECR ion source for high-intensity heavy-ion acceleration, (2) development of a negative-ion source for production of high-intensity neutron beam, (3) study of unstable nuclei mass-separated with a ion-guide type isotope separator on-line, and (4) study of the nuclear magnetic moment using perturbed angular correlation method. At the instrumentation research division, (1) development of the beam transport for high-resolution measurement of the (p, n) reaction, (2) study of the proton/neutron density distributions using the isobaric-analog state, and (3) study of the pionic modes in nuclei by the spin-dipole states.

Accelerator Science Group

Professor	:	Hideaki Yokomizo and Shoji Nagamiya
Associate Professor	:	Osamu Sasaki

High Intensity Proton Accelerator (H.Yokomizo & S.Nagamiya)

From Fiscal Year 2001 a new accelerator project to provide high-intensity proton beams proceeded into its construction phase. This project is conducted under a cooperation of two institutions, KEK and JAERI. The accelerator complex will provide 1 MW proton beams at 3 GeV and 0.75 MW beams at 50 GeV. By using these beams three major scientific goals will be pursued: 1) nuclear-particle physics primarily with kaon and neutrino beams from the 50 GeV Synchrotron, 2) life and material sciences with neutron and muon beams from the 3 GeV Synchrotron, and 3) R&D for nuclear transformation with neutron beams from the injector linac. The accelerator complex will be constructed at the JAERI-Tokai site.

Study on Detectors for Large Scale Experiments (O.Sasaki)

Large Hadron Collider (LHC) experiments at the center-of-mass energy of 14 TeV start in 2007 at CERN (Switzerland). An exciting new physics is expected, such as a discovery of Higgs and SUSY particles. A Japanese group is involved in the ATLAS experiment which includes many sub-detectors, e.g. inner trackers, calorimeters, muon spectrometers and magnets system. A major contribution from Japan is construction of a muon trigger chamber system. We are developing and building muon chambers, front-end electronics, trigger and readout circuits and the DAQ system using innovative techniques.

Low Temperature Physics Group

Associate Professor : Anju Sawada

(http://www.lowtemp.phys.tohoku.ac.jp/)

Low temperature physics is one of the most important disciplines in the fundamental physics. We are interested in quantum fluids such as electron liquids in the low temperature region. ^{3}He-^{4}He dilution refrigeration and nuclear demagnetization are our cooling methods down to 10^{-5} K. The major subject of our present research is quantum Hall effect.

The quantum Hall effect arises in two-dimensional electron system at low temperature and high magnetic field. The effect is very remarkable: at certain values of magnetic field the magnetresistance drop to zero, as if the effective conductance was infinite. Futher, there are plateaus of the Hall resistance near these same values of magnetic field, and the values of the Hall resistance at the plateaus are accurately equal to (25.8128075/integer) ohms, where 25.8128075 is the value of h/e^2 expressed in ohms.

Specially, macroscopic quantum interlayer coherence is expected to be observed in certain quantum Hall states of the bilayer electron system. It implies that the quantum Hall state is one of the Bose condensation states. This research will also make an academic contribution to establish the exotic statistics of particles intrinsic to the low dimensional space.

Magnetic Correlations Research Group

Professor : Satoru Kunii

(http://hiroshi.phys.tohoku.ac.jp/)

Magnetic properties of rare-earth compounds have attracted much attention due to the variety of ground states they exhibit, ranging from metallic and semiconducting behavior with localized f-electrons, through heavy-fermion superconductors, metallic Kondo lattices and Kondo insulators, to itinerant f-electron magnetism.

In Japan our group was the first to start to study these topics and the results obtained so far have contributed much to the understanding of the fundamental aspects of solid state physics. There are two ways to develop this field of physics: One way is to purify the known samples and to investigate physical properties in more detail. The other way is to search for new compounds and to build up new concepts of physics. In our group we have many kinds of apparatus to grow crystals (for example, a high-frequency induction furnace, an infrared mirror imaging furnace and an arc-melting furnace) and several measuring systems allow the investigation of the interesting transport and magnetic properties. Up to now we have mainly studied binary rare-earth compounds which contain boron element. Such compounds exhibit a variety of exciting phenomena like Kondo insulator, heavy Fermion and dense Kondo behavior.

Microscopic Research on Magnetism Group

Professor : Hideya Onodera
Associate Professor : Shigeru Takagi
Assistanr Professor : Aya Tobo

(http://www.mrm.phys.tohoku.ac.jp/)

Highly correlated electron systems in 5f-, 4f- and 3d-compounds as well as low-dimensional organic compounds show various interesting physical properties such as metal-insulator transition, valence fluctuation, heavy-electron behavior, multipolar ordering and low-dimensional quantum spin behavior.

We are exploring new target compounds and preparing high-quality samples by ourselves. In addition to various measurements on magnetic properties by basic methods, we are investigating these systems mainly through microscopic methods of Nuclear Magnetic Resonance (NMR) and Mössbauer spectroscopies. Generally in solids, nuclear magnetic moments are coupled to the electronic spin with modest strength, and this modestness makes these methods very powerful microscopic tools to probe the electronic states of the highly correlated electron systems. We are also performing neutron scattering experiments in order to study the magnetic structures and magnetic excitation behavior. High pressure is also very powerful in the study of these systems, because it can tune continuously and without disturbing the periodicity of the lattice the underlying delicate balance between itinerancy and localization in these systems. The combination of some of these methods can be quite powerful, and this has been constituting a frontier of our recent research.

Materials Structure Physics Group

Professor : Youichi Murakami
Associate Professor : Kazuaki Iwasa
Assistant Professor : Takeshi Matsumura , Hironori Nakao

(http://calaf.phys.tohoku.ac.jp/)

To understand various phenomena resulting from interactions among charge, spin and orbital degrees of freedom, we take systematic approaches; searching for typical materials, growing high quality single crystals, measuring fundamental properties, and performing neutron and x-ray scattering. We also develop new instruments and experimental methods to contribute to the scattering science.

We own and operate a conventional triple-axis spectrometer with polarization analysis option (TOPAN) at the JRR-3M research reactor in Japan Atomic Energy Research Institute (Tokai). X-ray scattering experiments are performed at a 4-circle spectrometer with a rotating anode in our group, and in cooperation with various synchrotron radiation facilities such as Photon-Factory (Tsukuba), SPring-8 (Harima), and NSLS (BNL, USA).

Our recent research activities cover Mn perovskite oxides showing colossal magnetoresistance, Ti and V perovskite oxides, Cu perovskite fluorides, and quadrupole ordering in rare-earth compounds.

Low-Dimensional Quantum Physics Group

Professor : Naoki Toyota
Associate Professor : Hiroshi Matsui

(http://ldp.phys.tohoku.ac.jp/)

In an interdisciplinary way between chemistry and physics, our group is studying fundamental electronic functions like conductivity, superconductivity, magnetism, and dielectricity on low-dimensional charge transfer salts, nanoporous molecular materials, and biological systems such as DNA. There are highly confined electron's motional degrees of freedom in a plane, chain or topologically curved channels. With dynamical conductivity measurements up to terahertz wave, our strategic targets are placed on the following materials.

1. Quasi two-dimensional $(BEDT\text{-}TSF)_2MX_4$ (M = Fe, Ga and X = Cl, Br) salts ((bis)ethylenedithio-tetraselenafulvalene) undergo superconductivity, metal-insulator transition, and magnetic ordering. Recently we found, in the salt with $FeCl_4$ anion, quite novel dielectric phenomena in a high temperature metallic phase followed by antiferroelectric ordering associated by antiferromagnetic insulator transition at 8.3 K.

2. Novel carbon mesoporous crystals with topologically curved channels like CMK-n (n = 1 - 4) synthesized by Prof. R. Ryoo's group (KAIST in Korea). Carbon nanotubes grown in channel cavities with diameter of 0.5 - 1.0 nm of $AlPO_4$-5 zeolite synthesized by Prof. Z. Tang's group (HKUST in China).

3. Highly oriented DNA (Prof. T. Kawai's group in Osaka). The microwave conductivities and infrared radiation have been successfully measured for various DNA samples.

Photoemission Solid-State Physics Group

Professor : Takashi Takahashi
Assistant Professor : Takafumi Sato

(http://arpes.phys.tohoku.ac.jp/)

We study the electronic structure of strongly correlated electron materials with ultrahigh-resolution angle-resolved photoemission spectroscopy (ARPES). Our current interest is on high-temperature cuprate superconductors, novel boride compounds, new carbon materials such as carbon nanotubes etc. We have constructed/improved an ultrahigh-resolution ARPES spectrometer in our laboratory and the present energy resolution (less than 1 meV) is among the world-best records.

On-going researches: (1) electronic structure and mechanism of high-temperature superconductors, in particular, superconducting "quasiparticles" near the Fermi level, (2) mechanism and origin of high-temperature superconductivity of magnesium diboride (MgB_2), (3) mechanism of charge-density wave (CDW) transition in low-dimensional materials, (4) electronic structure of new carbon materials (fullerenes, nanotubes etc.), and (5) electronic structure of strongly-correlated *f*-electron materials.

Solid State Physics on Nano-Network Solids

Professor : Katsumi Tanigaki

(http://sspns.phys.tohoku.ac.jp/)

We are currently studying nano size materials comprised of IV^{th}-group elements of C, Si, Ge and Sn, for achieving new insights to fundamental understanding in solid state physics of nano materials, as well as development of advanced electronic devices in the next generation. The most typical cluster is C_{60}, where sixty carbon atoms are self-assembled to a polyhedral cluster with high symmetry. Other IV^{th}-group elements like Si, Ge and Sn have recently been noticed to make similar polyhedra of IV_{20}, IV_{24} and IV_{28} cage clusters. One of the prominent things on these large size clusters is the fact that various types of crystals can be constructed ranging from van der Waals crystals to covalent ones. Phonons ranging from intra-cluster to lattice vibrations play an important role for determining the electronic states, and such situation is very different from that of the conventional materials. Phonons, conduction-electrons and magnetic-electrons interplay to produce electronic properties that cannot be obtained in the conventional materials. The most important researches in this century shall be nano materials science and technology. We are exploring novel materials on a basis of nano network materials and carrying out experiments towards this future dream.

Very Low Temperature Physics Group
- Center for Low Temperature Science -

Professor : Haruyoshi Aoki
Associate Professor : Akira Ochiai
Assistant Professor : Noriaki Kimura

(http://www.clts.tohoku.ac.jp/index.html)

Very Low Temperature Physics Group of Center for Low Temperature Science performs the experimental researches in condensed matter physics at very low temperatures, in high magnetic fields and under high pressures. Besides the developments of new techniques and detection systems under such extreme conditions, synthesis of novel materials and growth of high quality single crystals are other major activities of the group. The following topics are currently under investigation.
1. Physics related with orbital degrees of freedom.
2. Low dimensional charge order and related phenomena.
3. Quantum critical point and electronic structure.
5. New high T_c superconductors.
The Center also supports versatile researches at low temperatures in Tohoku University.

Superconductivity Physics Group

Professor : Norio Kobayashi
Associate Professor : Takahiko Sasaki
Assistant Professor : Terukazu Nishizaki, Naoki Yoneyama and Kazutaka Kudo

(http://ltp.imr.tohoku.ac.jp/)

The phenomenon of superconductivity is a remarkable example of quantum effects operating a truly macroscopic scale. Our purposes are to clarify its microscopic mechanism and to investigate interesting phenomena accompanying with an appearance of superconductivity. By the discovery of the high-T_c cuprate, the studies on the superconductivity take on a new aspect. Regardless of tremendous efforts of the physicists in the world, its mechanism has not yet been clarified. There exists another interesting superconducting system called as organic superconductors. In both systems, a strong anisotropy in electron system should play an important role. In order to understand the mechanisms of such unconventional superconductivity, we are studying the thermal, transport and magnetic properties. In these superconductors, very interesting phenomena in magnetic field such as the existence of a vortex glass, vortex melting etc. are also observed, which are very different from those in conventional superconductors. We are studying such phenomena by investigating microscopic electronic states using a low temperature scanning tunneling microscope (STM) in magnetic field as well as macroscopic properties such as transport, magnetic and magneto-transport properties in high magnetic fields up to 30 T.

Metallic Magnetism Group

Professor : Kazuyoshi Yamada
Assistant Professor : Kenji Ohoyama, Masaki Fujita, Haruhiro Hiraka

http://www.yamada-lab.imr.tohoku.ac.jp/

We explore quantum mechanical exotic phenomena originating in degree of freedom on spin and orbital moments of $3d$ or $4f$ electrons: for instance, high T_{C} superconductivity, electronic quadrupolar ordering, electronic charge segregation and so on.

We offer a challenge of discovery of new materials or new systems exhibiting such exotic phenomena and to make clear the mechanism from quantum mechanical point of view we grow and utilize single crystals with high quality for our experimental study.

Our main experimental method is neutron scattering, one of the most powerful and direct microscopic methods for magnetic systems. Neutron scattering can be applicable to study not only spatial spin arrangement but also time and space correlations of dynamical spin fluctuation. Thus the results of detailed neutron scattering experiments on high quality samples provide us an opportunity to revisit the microscopic origin of magnetism.

For our investigation, we have installed and maintained two neutron diffractometers, HERMES and KSD, at Japan Atomic Research Institute, Tokai. We also perform neutron scattering experiments in collaboration with scientists all over the world (USA, France, UK, Germany etc.).

Nanostructured Materials Physics Group

Professor : Yoshihiro Iwasa
Associate Professor : Yasujiro Taguchi
Assistant Professor : Taishi Takenobu and Shin-ichiro Kobayashi

(http://iwasa.imr.edu/)

Making functional materials and devices with nanoscale units is the goal of our research. Particularly, we are currently interested in nanocarbons such as carbon nanotubes and fullerenes, and organic molecules, which are regarded as key materials for nanotechnology, since these clusters or molecules obtain electronic functionalites both in solid and single molecular forms, including conductivity, even superconductivity, magnetism, or molecular transistor activity. In these properties, the π-electrons play crucial roles. Understanding the fundamental principle and control of the π-electron system are highly required for our purpose. We are investigating funadamental physical properties of π-electrons in the nanocscaled carbon clusters and molecular materials. Furthermore, based on this achievement, we are trying to make new functional bulk materials and molecular electronic devices.

Low Temperature Material Science Group - Center for Low Temperature Science

Associate Professor : Tsutomu Nojima
Assistant Professor : Shintaro Nakamura

(http://ltsd.imr.tohoku.ac.jp/index-e.html)

Our group, composing Center for Low Temperature Science, studies the low-temperature electrical properties of high-T_c superconducting and highly-correlated magnetic materials, such as Cu-oxides, Mn-oxides and Ce-based-compounds. In addition to understanding the basic properties of these materials, exploring and clarifying unknown physical phenomina in the form of thin films, multilayers and diluted alloys are our interests. The following subjects are now focused.

1) Spin injection effect on the superconducting properties in Cu-oxide/Mn-oxide (superconductor/ferromagnet) tunnel junctions.
2) Studies of vortex dynamics in high-T_c superconducting films with artificially introduced defects.
3) Studies of quantum phase transition and non-Fermi liquid state in diluted alloys of Ce(4f) compounds by specific heat, magnetization, and transport measurements.
4) Superconducting properties of MgB_2 films and single crystals in magnetic fields.

Actinide Physics Group

Professor : Jun′ichiro Mizuki
Associate Professor : Naoto Metoki and Yasuji Muramatsu

Study of $5f$ electron system in actinide compounds is one of the most important subject in condensed matter physics. For example, the discovery of ferromagnetic superconductors UGe_2 and URhGe and the high-T_c heavy fermion superconductivity $PuCoGa_5$ attract strong interest in the field of strongly correlated electron systems. The purpose of this research group is to construct a new concept in materials science by means of neutron and synchrotron radiation x-ray scattering study of the actinide compounds. This group is established with the collaboration of Tohoku university and Japan Atomic Energy Research Institute, JAERI. This collaboration has two advantages. First, JAERI is the international center of actinide science, where actinide element can be easily treated and high quality single crystalline samples are grown by sample preparation group. There are many collaborating research groups; neutron scattering, NMR, and theory groups. Second the research reactor JRR-3 and SPring-8 are the powerful neutron and x-ray source, where JAERI staff has own sophisticated instruments for our purpose.

Surfaces of solid, liquid, and interfaces between them, are also studied in SPring-8. Surface and interface physics is fascinating both from a fundamental and a technological point of view. Structural studies of these systems are of considerable importance for the elucidation of surface and interface phenomena. We would like to focus on the investigation on the MBE crystal growth of III-V semiconductors by in-situ X-ray diffraction, and on the interface structure of electro-chemical system in order to understand and control the electron transfer occurred at the interface.

Synchrotron Radiation and Photoelectron Physics Group

Associate Professor : Shoji Suzuki

(http://www.srpe.phys.tohoku.ac.jp/)

We are studying the electronic structures of solids and solid surfaces with photoemission and inverse-photoemission spectroscopy. Our particular interest is on quantum confinement effects on the electronic structures in the low-dimensional nano-structured metals, such as metallic nanofilms and nanowires grown on the various substrates and surface-passivated metallic nanoparticles. In addition, the electronic structures of strongly correlated electron systems such 4f/5f materials are also studied. The design study of a third generation, high-brightness, 1.5 Gev synchrotron light source is promoted in collaboration with several members from the Laboratory of Nuclear Science and some institutes in the university.

Surface Physics Group

Professor	:	Shozo Suto
Assistant Professor	:	Kazuyuki Sakamoto

(http://surface.phys.tohoku.ac.jp/)

We are interested in the physics at surfaces, interfaces, nano-structures and other novel low dimensional structures, where electrons behave quite differently from the electrons in the bulk. The first goal of our group is to investigate electronic states and phase transitions in the low dimensional structures. The second goal is to understand the surface potential to control initial stages of film growth and nano-structure formation. The third goal is to understand electronic excitations at metal and semiconductor surfaces manifested by surface plasmons and inter-band transitions. Our main experimental techniques are high resolution electron energy loss spectroscopy (HREELS) with 0.5 meV resolution, photo-electron spectroscopy(PES) and variable temperature scanning tunneling microscopy(VT-STM). The low energy electrons of about 10eV are very sensitive for vibrational and electronic excitations. We measure the surface band structures using an ultraviolet light source and the core level states at surface atoms using a soft xray source. In order to correlate the macroscopic information on electronic and vibrational excitations with microscopic structures, we have constructed a combined measurement system of HREELS and STM.

Laser Spectroscopy Group

Professor	:	Seishiro Saikan
Associate Professor	:	Masayuki Yoshizawa
Assistant Professor	:	Akitoshi Koreeda

(http://www.laser.phys.tohoku.ac.jp/)

In the Nonlinear Laser Spectroscopy Group, the present research interest has been focused on the phonon physics, in particular, 3-phonon process in both crystalline and amorphous materials. The temperature dependence of hypersonic attenuation and the low energy excitation in amorphous materials has been investigated by using nonlinear laser spectroscopy such as Brillouin gain spectroscopy and Impulsive Stimulated Thermal Scattering. On-going research works: Correlated fields hole burning spectroscopy in Tm:YAG; Development of high precision Brillouin gain spectrometer ; Study of hypersonic attenuation in crystals and glasses; Light beat fluorescence line narrowing spectroscopy; Ultra-fast spectroscopy in organic materials; Development of frequency-stabilized ECDL(semiconductor laser).

Biophysics Group

Professor	:	Kazuo Ohki
Associate Professor	:	Hidetake Miyata
Assistant Professor	:	Tetsuhiko Ohba

(http://www.bio.phys.tohoku.ac.jp/)

Major purpose of the Biophysics group is to elucidate relationship between structure/physical property and function in biomembranes. And the researches are performed from viewpoints of physical property of biomaterials and cell biophysics. The method developed in this laboratory, which is an imaging system to observe spatial distribution of physical property (membrane fluidity) under a microscope at video rate, is applied to the study on the relationship between membrane fluiditye and various cell functions (e.g. differentiation, apoptosis, endocytosis and temperature acclimation). A fluorescence microscope equipped with optical tweezers and evanescent wave excitation system is used to investigate molecular forces and interfacial phenomena; the studies of mechanism of cell shape change, coupling between the bio-signaling, physical events in phagocytosis, analysis of cell adhesion and dynamics of cytoskeleton.

We have experimental facilities for preparing artificial and biological membranes and culturing cells, in addition to instruments for chemical analysis of biomaterials. And various apparatus are available for measuring phase transition and phase separation of membranes, molecular dynamics, local viscosity, membrane density, diffusion of lipid and protein molecules on biomembranes, flow of bio-molecules in a cell and so on.

Solid State Photophysics Group

Professor	:	Teruya Ishihara
Associate Professor	:	Shinichiro Iwai
Assistant Professor	:	Masanobu Iwanaga

(http://www.sspp.phys.tohoku.ac.jp/)

By combining the progresses of materials sciences, nanofabrication and ultrafast laser techniques, it is now possible to explore new physics on light-matter interaction. At the moment, we are focusing on the two subjects below:

1) **Photonic crystals**: Photonic crystal is a periodic array of dielectrics in the scale of light wavelength. By using ultra fine fabrication techniques, we realize unconventional electromagnetic environment, where interactions with excitons in semiconductor and plasmons in metal may lead to exotic phenomena.

3) **Ultrafast photoinduced cooperation phenomena in strongly correlated electronic systems**: In the strongly correlated electron system(SCE), photoinduced novel phenomena such as photoinduced phase transition are expected to occur. Ultrafast dynamics of the photoexcited state in SCE are investigated by using 20-200 femtosecond lasers in wide (near UV - mid IR) wavelength region. The target materials are 3d transition metal Mott insulators, charge-ordered or charge-transferred organic complexes.

Lattice Defect Physics Group

Associate Professor : Ichiro Yonenaga

(http://www.imr.tohoku.ac.jp/index-e.html)

Lattice defects, i.e. vacancies/interstitials, impurities, dislocations, stacking faults, etc., control crucially the physical properties of semiconductor materials. Thus, the understanding of the structure and nature of such lattice defects is quite important for developing new semiconductor devices in future. The aims of our research group are to characterize the electrical, optical, and strucutral properties of defects, to observe their intrinsic atomic structure, and to clarify their generation/formation mechanism in a variety of semiconductor crystals such as Si, GeSi, GaAs, GaN, and ZnSe. The other aim is, with the knowledge established in the above research, to create new semiconducting materials. Some of the topics of our recent research are following: (1) investigation of electronic and optical properties of individual defects and their complexes generating from the reaction with impurities, (2) investigation of dislocation dynamics and plasticity of semiconductors for controlling dislocation generation and dislocation-defect (impurity) interaction, (3) development of new technology for defect recognition, and (4) creation/growth of next-generation semiconductor crystals with unique properties.

Crystal Growth Physics Group

Professor	:	Kazuo Nakajima
Associate Professor	:	Noritaka Usami
Lecturer	:	Gen Sazaki
Assistant Professor	:	Kozo Fujiwara

(http://www.xtalphys.imr.tohoku.ac.jp/)

In the 21'st century, opto-electronic conversion elements such as solar cells, opto and electronic devices such as semiconductor lasers and ULSI, biological macromolecules such as protein would be the essential materials to solve the serious problems: ex. energy crisis, environmental pollution and advanced industrial foundation. All of these materials are essentially based on crystals and the development of the novel functional crystals has the key to solve the problems. The aim of our group is to develop novel crystal growth techniques and new functional crystals on the basis of the crystal growth physics from semiconductor to organic materials. The crystal growth mechanism is investigated from both experimental and theoretical viewpoints.

Now, we are focusing on the following subjects:

(1) Studies on the materials for solar cells

(2) Growth of multi-component bulk substrate crystals and studies on hetero-epitaxial structure with controlled stress

(3) Studies on the mechanism of crystal growth

(4) Studies on the crystal growth of organic materials

Surface / Interface Science Group

Professor : Toshio Sakurai
Associate Professor : Tadaaki Nagao
Assistant Professor : Yasunori Fujikawa, Jerzy T. Sadowski, and Yukiko Yamada-Takamura

(http://apfim.imr.tohoku.ac.jp/)

In Surface / Interface Science group at Institute for Materials Research, we have been studying atomic properties on solid surfaces and interfaces. Our works using our own developed scanning tunneling microscope (FI-STM), high-momentum-resolution electron energy loss spectrometer (ELS-LEED), ballistic electron emission microscope (BEEM), atom-probe field ion microscope (AP-FIM), are highly recognized internationally, and we are cited as one of the ten best scientific groups in the world (Science Watch, Oct. issue, 1995). Our research subjects include semiconductors (elemental and compound), metals (elemental, alloy and amorphous), and organic materials (fullerene and pentacene molecules). Some of the topics of our recent research are following: (1) atomic structure and electronic properties on surfaces of MBE grown GaAs, InAs and GaN, by using variable-temperature STM/AFM (2) nanoscale characterization and electronic excitations of ultrathin films by spot profile analysing low-energy electron diffraction (SPA-LEED) and ELS-LEED (3) Ge growth on vicinal and high-index Si surface by STM (4) development of low temperature BEEM and a study of electron transport through nano-scale domains of interfaces on Si surfaces (5) formation mechanisms of nano-crystalline materials (6) High resolution electron energy loss spectroscopy (HREELS) for the structural and the chemical measurements on surfaces.

Solid State Ion Physics Group

Professor : Junichi Kawamura
Associate Professor : Yukio Shibata
Assistant Professor : Osamu Kamishima

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Our group is working mainly on solid state ionic materials to understand physics of ion dynamics in maters. Local structures and electronic structures of disordered materials are studied through interaction between light and materials by optical absorption, light emission and scattering. Especially, ”Superionic conductor”, which is a typical disordered solid state material with ionic mobility even as high as in liquid, is studied. (1) Development of high-resolution spectroscopy such as site selective spectroscopy and hole burning spectroscopy: Study on local structure in superionic conductors. (2) Development of non-linear spectroscopy using femto-second laser: Direct observation of ionic motion in materials. (3) Optical absorption /reflection and photoemission spectroscopy in vacuum ultraviolet region: Study on electronic band of superionic conductors. (4) Development of light scattering spectroscopy in low frequency region: Study on interaction between low energy excitation and ionic motion in solids. (5) Synthesis of superionic superlattice using laser ablation method: Study on fast ion dynamics in superionic superlattice.

Correlated-electron Solid State Physics Group

Professor : Taka-hisa Arima
Assistant Professor : Kimihiro Ishi

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1. Non-reciprocal magneto-optics in non-centrosymmetric magnetic materials Magnetic materials without the inversion symmetry should show 'non-reciprocal' magneto-optics. Since the novel magneto-optics is directly related to the symmetry of materials, it would be a powerful probe of magnetism in biomaterials, artificial nano-structure, and so on. We are now developing the technique for the measurements of various non-reciprocal magneto-optical effects in infrared, visible, ultraviolet light, and x ray. We also study the optical process relevant to the novel magneto-optics.

2. Material design and physical properties of multi-ferroic materials

In some magnetic-electrics, or so-called multi-ferroics, polarization can be modified by the application of magnetic fields. Though the magneto-electric effect was discovered many years ago, recently multi-ferroic materials are attracting much interest as possible storage materials. We have been collaborating with other group and found that perovskite-like manganese oxides show a giant magneto-electric effect. We study the mechanism of the giant magneto-electric effects and design other multi-ferroic materials.

3. Observation of charge/orbital ordering in strongly correlated electron systems

In many transition-metal oxides, insulating phases would be characterized by spatial ordering in charge and/or orbital degrees-of-freedom. The ordering plays a key role in the metal-insulator transition. For example, colossal magneto-resistance in perovskite-like manganites results from the magnetic-field-induced melting of charge ordering. We have been studying charge and orbital ordering in transition metal oxide materials by means of synchrotron x-ray and neutron diffraction.

Electron-Crystallography and -Spectroscopy Group

Professor : Masami Terauchi
Associate Professor : Kenji Tsuda

(http://xes.tagen.tohoku.ac.jp/)

(a) Electron Crystallography (Electron-diffraction and -microscopy)

Crystal symmetries, microscopic crystal structures, atom positions, Debye-Waller factors and bonding charge distribution are studied by convergent-beam electron diffraction (CBED) and electron microscopy using an energy-filter transmission electron microscope. These techniques are applied to phase transformations of ferroelectric substances, higher-dimensional structures of quasicrystals and incommensurate crystals, charge/orbital-ordering phenomena of strongly-correlated electron systems and lattice defects and interface structures of semiconductors.

(b) Electron Spectroscopy (EELS and SXES based on electron microscopy)

Electronic structures of solids in nm-scale specimen area are studied by a high energy-resolution electron energy-loss spectroscopy (EELS) microscope and a newly developed soft-X-ray emission spectroscopy (SXES) microscope. These studies include a systematic investigation of carbon allotropes (C_{60},C_{70},....., carbon and boron-nitride nanotubes), boron allotropes (pure and metal-doped α, β-boron and related boron compounds), band structures of oxide superconductors (Bi-, La-systems), the metal-insulator transitions of transition metal oxides, pseudo-gap structures of quasicrystals, the defect levels of semiconductors and multi-layer materials and plasmons in metals and alloys.

Structural Physics and Crystal Physics Group

Professor : Yukio Noda
Assistant Professor : Masashi Watanabe and Hiroyuki Kimura

(http://www.tagen.tohoku.ac.jp/labo/noda/index-j.html)

Material science is one of the key word to consider the modern society, and the structural and crystal physics gives a fundamental base for this field. Crystal has a regular arrangement of atoms. Some of structural phase transitions change physical properties of materials completely such like a transformation from a graphite to a diamond. Sometimes magnitude of such atomic shifts is only less than 0.1 Å. Diffraction technique can detect such a small change and reveals the law in a microscopic world. It seems very special investigation, but these studies are the bases of technologies such like an electrical condenser, a silicon wafer of semiconductor, a smart device of memory card, an optical device, a memory metal, an actuator of robotics, and so on. We use varieties of equipments. X-ray machines in our laboratory are very unique and useful to study the nature of phase transition phenomena, and we are still continuing to develop new machines such like a low-background vacuum X-ray photographic equipment for detailed crystal structure analysis below 4K. We sometimes use an X-ray diffractometer at SPring-8, which is the largest synchrotron facility in the world, to carry out the frontier experiments. Furthermore, we have constructed a neutron 4-circle diffractometer at Japan Atomic Energy Research Institute at Tokai, and we are investigating the role of crystal and magnetic structures for the properties of materials.

Laser Quantum Optics Group

Professor : Yusaburo Segawa
Associate Professor : Bao-ping Zhang and Kodo Kawase

(http://www.phys.tohoku.ac.jp/shoukai/lazer-q-e.html)

The laboratory of Laser Quantum Optics aims to understand interactions between light and materials and to apply such phenomena to photo-functional devices. When the dimension of a material is close to the de Broglie wavelength of an electron (several to tens of nanometers), the material reveals new features associated with changes in the electronic band structure. These modifications, known as quantum confinement effects, are being extensively studied and are used to artificially control the optical properties of materials. In order to study the quantum confinement effect, this laboratory is working on the development of growth techniques of ionic crystals (CuCl) and II-VI semiconductors (ZnO, CdSe, ZnSe) quantum structures such as quantum wells, quantum wires and quantum dots. On the other hand, it is known that light with a particular wavelength can no longer exist in certain periodic structures and excited atoms can no longer emit light of this wavelength. Thus, it is theoretically forecast that natural light emission may be artificially controllable in such structures. Thus, the laboratory of Laser Quantum Optics is endeavoring to develop new optical devices that utilize the precise geometrical arrangements of materials to control both electronic band structures and photonic band structures and thereby obtain optimum control of optical properties.

Guide to Graduate School, Department of Physics, Tohoku University

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