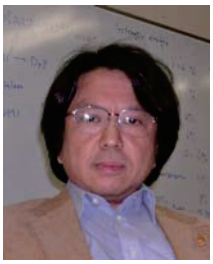


Title of Project : A global research and development program of a state-of-the-art detector system for ILC

Hitoshi Yamamoto
(Tohoku University, Graduate School of Science, Professor)

Research Area : Experimental Particle Physics

Keyword : Experimental Particle Physics, Advanced Detectors, Computational Physics

【Purpose and Background of the Research】

The proposed international linear collider (ILC) has far superior sensitivity for physics within its energy reach than the LHC that will provide a glimpse into the Terascale. The resolutions required for detectors at the ILC far exceed those of the LHC detectors and the detector R&Ds for the ILC have been significantly raising the standard of the field in the recent past.

The objective of this program is to prepare the ILD detector technically and organizationally to be ready to be constructed when the scientific and political climate allows it to start. To do so, we will complete, in a timely manner, a detector design that is fully capable of realizing the physics potential of the ILC, and develop the necessary key detector elements focusing on vertexing, tracking, and calorimetry. We pursue this goal within international frameworks, closely working with international collaborators.

A project as large as the ILC cannot be realized without understanding and support of general public. Communicating the values of basic sciences such as the ILC with the public is also an important goal of this program.

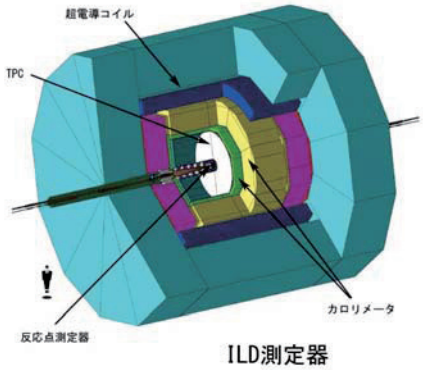
【Research Methods】

In order to achieve the required quark energy resolution, we employ the particle flow algorithm (PFA) where charged particles are measured by tracking devices while neutral particles measured by the calorimeters. In addition, the momentum and vertex resolutions also need to surpass the current state of the art.

The PFA is realized by calorimeters with number of channels that is greater than LHC by three orders of magnitude. The required momentum resolution is achieved by a time projection chamber (TPC) read out by GEM (Gas Electron Multiplier) where the mass of the device is reduced by factor 6 leading to momentum resolution that is factor of 10 smaller compared to the current standards of TPC. The necessary vertex resolution is provided by FPCCD (Fine Pixel CCD) whose pixel size is about 1/1000 of that at LHC.

【Expected Research Achievements and Scientific Significance】

We will realize a detector for ILC based on the PFA concept. The technologies developed for the purpose are novel ones that open new horizons for detectors in the field of high-energy physics. If a linear collider is to be built as planned, the results of this program will be fully utilized. In addition, these detector technologies are likely to become new standards in this field with many applications in nuclear physics, astronomy, biology, and medicine.



ILD測定器

【Publications Relevant to the Project】

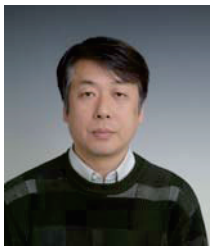
[1] http://www.linearcollider.org/, ILC Reference Design Report vol.1-4 (2007):
[2] The International Large Detector (ILD) Letter of Intent, ILD group, http://www.ilcild.org/documents/ild-letter-of-intent/LOI.pdf
[3] "Construction and Commissioning of the CALICE Analog Hadron Calorimeter Prototype", The CALICE collaboration, C. Adloff, et al., JINST 5 P05004 (2010).
[4] "CCD-based vertex detector for GLC", Y. Sugimoto, et al., Nucl. Instrum. and Meth. A549: 87-92 (2005):
[5] "Study in a beam test of the resolution of a Micromegas TPC with standard readout pads", The LCTPC Collaboration, D.C.Arogancia, et al., Nucl. Inst. And Meth. A602 403-414 (2009);

【Term of Project】 FY2011-2015

【Budget Allocation】 428,300 Thousand Yen

【Homepage Address and Other Contact Information】

http://epx.phys.tohoku.ac.jp/ilcsuishin-en/
yhitoshi@epx.phys.tohoku.ac.jp



Title of Project : High-resolution Spectroscopy of Many-Body systems with Multi-Strangeness

Tomofumi Nagae
(Kyoto University, Graduate school of Science, Professor)

Research Area : Particle/Nuclear/Cosmic Ray/Astro physics

Keyword : Nuclear physics (experiment)

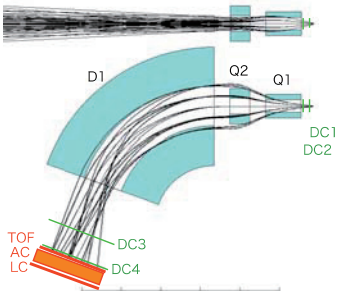
【Purpose and Background of the Research】

The spectroscopic information of both Ξ hypernuclei and double-Λ hypernuclei will give us information of Ξ N interaction, Λ Λ interaction, and their coupling through the Ξ N-Λ Λ channel. Such experimental information of baryon-baryon interaction with strangeness (S)=-2 is almost nothing at this moment. Nevertheless, several baryon-baryon interaction models have been theoretically developed. They put their basis on the so-called realistic nuclear force which reproduces a plenty of nucleon-nucleon scattering data, and extend it to the flavor SU(3) baryon-baryon interactions based on a traditional meson-exchange picture. The recent spectroscopic information of the S=-1 systems, such as Λ hypernuclei and Σ hypernuclei, gives an essential role to construct the baryon-baryon interaction models. Therefore, the experimental information on the strength of the central attraction of the Ξ N interaction and its coupling strength in the Ξ N-Λ Λ channel could be an important key to constrain the interaction models.

【Research Methods】

In this research, the (K^-,K^+) reaction spectroscopy is conducted for the first time by using the good energy resolution and large acceptance spectrometers together with the world-highest intensity K^- beam available at J-PARC.

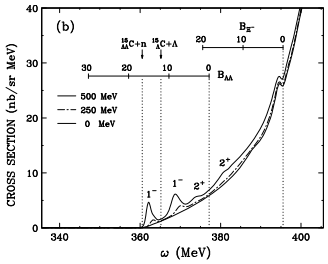
The new spectrometer is designed to have a momentum resolution of better than 0.05%(FWHM) and the solid-angle acceptance larger than 70 msr. The new spectrometer has a QQD configuration to have a better optical property.



It will become possible to measure the excited levels of double-Λ hypernuclei together with the bound states of Ξ hypernuclei in the (K^-,K^+) missing-mass spectra.

【Expected Research Achievements and Scientific Significance】

We will carry out the (K^-,K^+) spectroscopy to observe Ξ hypernuclei and double-Λ hypernuclei in a wide excitation energy range of ~40 MeV. The coupling between two types of hypernuclear bound states through the Ξ N-Λ Λ affects the energy levels of both Ξ hypernuclei and double-Λ hypernuclei. With the new spectrometer system, we will measure the ^{16}O(K^-,K^+) reaction, first. Then, we will investigate the iso-spin dependence and mass-number dependence of the Ξ N potentials by using ^{10}B, ^{7}Li and ^{28}Si targets.



【Publications Relevant to the Project】

- P. Khaustov, D.E. Alburger, et al., "Evidence of Ξ hypernuclear production in the ^{12}C(K^-,K^+)$^{12}{}_{\Xi}$Be reaction", Phys. Rev. C 61 (2000) 054603
- T. Harada, Y. Hirabayashi, A. Umeya, "Production of doubly strange hypernuclei via Ξ - doorways in the ^{16}O(K^-,K^+) reaction at 1.8 GeV/c", Phys. Lett. B 690 (2010) 363-368.

【Term of Project】 FY2011-2015

【Budget Allocation】 336, 200 Thousand Yen

【 Homepage Address and Other Contact Information】

http://www-nh.scphys.kyoto-u.ac.jp/~nagae/tokubetsu/index.html
nagae@scphys.kyoto-u.ac.jp

Title of Project : Cosmic evolution study by using a combination between the high sensitivity X-ray CCD and the super mirror

Hiroshi Tsunemi
(Osaka University, Graduate School of Science, Professor)

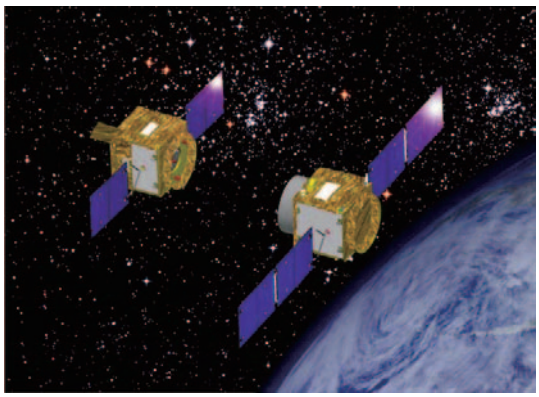
Research Area : Science and Engineering, Mathematical and physical sciences, Astronomy

Keyword : X-ray/ γ -ray astronomy

【Purpose and Background of the Research】

Our universe started from the Big Bang about 13.7 billion years ago and is still evolving. We can study its evolution by measuring of the brightness distribution of our universe. There are many Active Galactic Nuclei (AGN) that are believed to have giant black holes. AGN generate Cosmic X-ray background (CXB) that becomes the brightest around 40keV. Due to the technological constraint, X-ray observations with high sensitivity were done only below 10keV (soft X-ray). We need perform high sensitivity observation above 10keV (hard X-ray). With taking into account the CXB spectrum, a new frontier is left at hard X-ray band.

X-ray observation using X-ray focusing telescope is concentrated in the very narrow region in pointing mode. On the contrary, scanning observation for a large sky area is done by using non-focusing telescope. We have to cover various targets in brightness that cannot be done so far. We plan to observe a large sky area using a focusing super mirror covering the energy up to 80keV. We are eager to perform the observation to reveal the evolution of the universe based on our idea.



【Research Methods】

We will continue the scan observation in hard X-ray by using MAXI onboard the ISS that has no focusing telescope. ASTRO-H to be launched in FY2013 will observe hard X-ray using focusing telescope. It will focus on a pointing mode. In this context, we are planning to have the FFAST mission that consists of two small satellites. One carries a super mirror developed in Nagoya University, covering the X-ray energy up to 80keV. The other carries an SDCCD developed in Osaka University. The figure left bottom shows the FFAST image in orbit.

【Expected Research Achievements and Scientific Significance】

The FFAST mission will perform a scan observation of a large sky region by using a focusing super mirror for the first time. This will help us to reveal the evolution of the universe.

Formation flight projects were proposed in US and in Europe while they are cancelled. We will use the formation flight technology developed in JAXA. It will be the first mission from the engineering point of view.

【Publications Relevant to the Project】

Hiroshi TSUNEMI, Kiyoshi HAYASHIDA, Naohisa ANABUKI, Rui SAKAGUCHI, Hideyo KUNIEDA, Yasushi OGASAKA, Masayuki ITOH, Masanobu OZAKI, Isao KAWANO, and FFAST team, "High Energy X-Ray Sky Observation by the Formation Flight All Sky Telescope", Transaction of JSASS Aerospace Tech Japan, To_4_7-12, 2010

Hiroshi Tsunemi, Shutaro Ueda, Kazuo Shigeyama, Koji Mori, Shoichi Aoyama, Shinichiro Takagi, "Performance of a newly developed SDCCD for X-ray use", Nucl. Instrum. and Meth. 10.1016/j.nima.2010.08.118

【Term of Project】 FY2011-2015

【Budget Allocation】 424,800 Thousand Yen

【 Homepage Address and Other Contact Information】

http://wwwxray.ess.sci.osaka-u.ac.jp/ffast/FFAST/Top.html
http://wwwxray.ess.sci.osaka-u.ac.jp/OskXrayTlabHP/Tsunemi_Labo.html

Title of Project : Development of Medical Radionuclides Produced by Neutrons from Accelerator

Yasuki Nagai
(Japan Atomic Energy Agency, Nuclear Energy Research Collaboration Center, Invited Researcher)

Research Area : Particle/Nuclear/Cosmic ray/Astro physics, Physical chemistry, Radiation science

Keyword : Nuclear physics (experiment), Accelerator technology, Chemical analysis by nuclear methods, Nuclear medicine, Radiopharmaceuticals/Contrast medium, Therapeutic radiology

【Purpose and Background of the Research】

In Japan, radiopharmaceuticals containing 99mTc, the daughter nuclide of 99Mo, and 90Y have been used for diagnostics (900,000 diagnostic procedures per year) and cancer therapy, respectively. Both 99Mo ($T_{1/2}$=66 h) and 90Y ($T_{1/2}$=64 h) are imported constantly. However, an unscheduled shutdown of reactors, which have been used to produce 99Mo by using highly enriched 235U, has caused a crisis shortage of 99Mo worldwide. 90Y decays during the transportation, which causes a problem in formulating 90Y-radiopharmaceuticals. 67Cu and 64Cu are believed to become central radioisotopes (RIs) for diagnostics and therapy. Establishment of practical production method of these RIs has been a longstanding problem.

Present study aims to produce 99mTc, 90Y, 64Cu and 67Cu by using only accelerator neutrons. Produced RIs can be separated from irradiated samples by physical and/or chemical processes. Radiopharmaceuticals containing the RIs are administered into animals to measure the bio-distributions of the RIs, which are compared with that obtained by using radio-pharmaceuticals containing existing RIs to prove the quality of the RIs produced by the proposed approach.

【Research Methods】

99Mo, 90Y, 64Cu and 67Cu are produced using neutrons provided at the Fusion Neutronics Facility of Japan Atomic Energy Agency. Carrier free 99mTc, 90Y, 64Cu and 67Cu can be obtained by sublimation or ion exchange chemical separation. Using the carrier free RIs, appropriate ligands are used among existing radiopharmaceuticals for labeling. Both accelerator neutron and reactor neutron produced 99mTc and 90Y, and accelerator neutron produced 64Cu and 67Cu are formulated as various radiopharmaceuticals for imaging studies. Their bio-distributions are assessed in a rat model to test the usefulness of the RIs produced by accelerator neutrons. In order to carry out the present study, high intensity accelerator neutrons are obtained by fabricating a large copper disk coated with titanium to absorb tritium. An automatic RIs processing system, which enables to separate a large amount of 99mTc and 90Y from irradiated samples and to recover enriched 100Mo and 90Zr samples with high efficiency, is installed.

【Expected Research Achievements and Scientific Significance】

We can establish basic technologies required to ensure a reliable and constant supply of 99Mo and supply a fresh and high quality 90Y in Japan. A novel production method of 64Cu and 67Cu in large quantities is for the first time established. Domestic production of these RIs would also contribute to reduce the escalating cost of human health care and should play an important role in new developments of radio-pharmaceuticals. Because of unique features of the newly proposed RIs production method, such as the use of accelerator neutrons (accelerator operates constantly and reliably), a small yield of radioactive waste, and the nonuse of highly enriched 235U, a facility for treating RIs and storing produced radionuclides can be made compact. Hence, the proposed method is accepted worldwide as being reliable and cost effective. Moreover, since many useful RIs for medical application can be produced by employing the proposed method, a new frontier of diagnostics and therapy in nuclear medicine is formed, which should contribute to foster young generation in a new research field.

【Publications Relevant to the Project】

1) Production of 99Mo for nuclear medicine by ^{100}Mo(n,2n)^{99}Mo, J. Phys. Soc. Jpn. 78 (2009) 033201-1, 033201-4
2) Production of an isomeric state of ^{90}Y by fast neutrons for nuclear diagnostics, J. Phys. Soc. Jpn. 78, (2009) 113201-1, 113201-4

【Term of Project】 FY2011-2014

【Budget Allocation】 299,200 Thousand Yen

【Homepage Address and Other Contact Information】

Title of Project : Studies on the Synthesis of Highly Oxidized Complex Natural Products of Biological Significance

Keisuke Suzuki
(Tokyo Institute of Technology, Graduate School of Science and Engineering, Professor)

Research Area: Organic Chemistry

Keyword: Synthetic Organic Chemistry, Development of New Synthetic Method, Total Synthesis of Natural Products

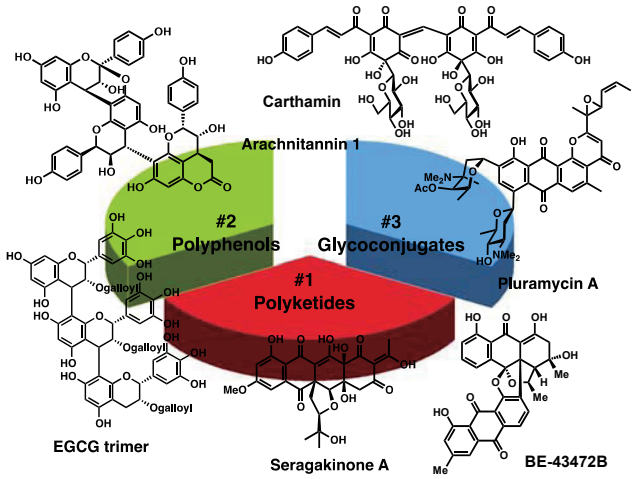
【Purpose and Background of the Research】

Spectacular advance of organic synthesis in the past decades have enabled facile access to organic compounds that play significant roles in various scientific and industrial fields. However, certain classes of compounds remain hardly accessible from the current status of organic synthesis. A typical example is the densely functionalized polycyclic compounds derived from the type-II polyketide biosynthesis, which constitutes an attractive class of compounds in view of the bioactivities. The potential bioactivities become even more attractive the hybridization with other biosynthetic products, e.g. sugars or terpenoids, while the synthesis becomes even more challenging.

As the synthetic targets for this five-year project, we selected *highly oxidized complex natural products*. To address synthetic challenges posed by such formidable synthetic targets, we will focus on the development of new synthetic strategies and tactics, hoping eventually to achieve the total syntheses, and contribute to the material and biological sciences.

【Research Methods】

Our target molecules are categorized into three classes as listed below: 1) polyketide-derived polycyclic compounds, 2) catechin-class polyphenolic compounds, 3) glycoconjugates. Sizable molecular diversity is generated by the conjugated oxidation/reduction and also by skeletal modifications including ring fission. The main obstacle is the general *complexity* of the molecules, making the synthesis / purification / analysis challenging. Some effective approaches have been developed *en route to* these intriguing, potentially useful classes of natural products.



【Expected Research Achievements and Scientific Significance】

Efficient strategies for constructing complex organic architectures are very important for enhancing the material-based science and technology, including biosciences because complex structures are exploited for modulating biological functions within the cell. This project deals with the exploration of new synthetic strategies and tactics that will allow the de novo construction of complex natural products and their derivatives that are otherwise inaccessible from the natural source or through conventional organic synthetic methods.

【Publications Relevant to the Project】

・"Integrated Synthetic Strategy for Higher Catechin Oligomers", K. Ohmori, T. Shono, Y. Hatakoshi, T. Yano, K. Suzuki, *Angew. Chem. Int. Ed.* **50**, 4862–4867 (2011).
・"Total Synthesis and Absolute Stereo chemistry of Seragakinone A", A. Takada, Y. Hashimoto, H. Takikawa, K. Hikita, K. Suzuki, *Angew. Chem. Int. Ed.* **50**, 2297–2301 (2011).
・"Lessons from Total Synthesis of Hybrid Natural Products", K. Suzuki, *The Chemical Record*, **10**, 291–301 (2010).

【Term of Project】 FY 2011-2015

【Budget Allocation】 333,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.chemistry.titech.ac.jp/~org_synth

Title of Project : Bioinorganic Chemistry of Oxidoreductases having Unique Active Site Clusters

Kazuyuki Tatsumi
(Nagoya University, Research Center for Materials Science, Professor)

Research Area : Bioinorganic Chemistry, Coordination Chemistry, Organometallic Chemistry
Keyword : Nitrogenase, Hydrogenase, Photosystem II, Transition Metal Cluster

【Purpose and Background of the Research】

An important and pressing mission of chemists has been to synthesize model active-sites of metalloenzymes in vitro and to elucidate the mechanisms of the biological functions, which would eventually lead to artificial enzymes equivalent or even superior to nature's. The investigation of reductases has made a rapid progress in recent years, unfolding novel structures and functions of the active centers consisting of metal sulfide/thiolate clusters, and greatly expanding our established knowledge of chemistry. On the other hand, the structure of photosystem II has been determined, revealing a unique manganese oxide cluster structure at the oxygen-evolving center.

In this project, we challenge the chemical synthesis of these metal sulfide/oxide cluster active sites, where a new method to build clusters in non-polar solvents will be utilized extensively in order to avoid degradation of meta-stable cluster structures. Based upon newly revealed model clusters, we will elucidate the biosynthetic mechanism of the cluster active sites and enzymatic functions.

【Research Methods】

1) Oxygen-evolving center of Photosystem II: We will synthesize [3Mn-Ca-4O-Mn] clusters using various bulky alkoxides in order to control the reactions, and their reactions will be examined.
2) Nitrogenase: Highly improved [8Fe-7S] P-cluster models compared to our early models will be synthesized, and their redox properties studied. Synthesis and reactions of FeMo-co model clusters will also be attempted.
3) Acetyl CoA synthase: [4Fe-4S] cluster will be conjointed to a series of our dinuclear nickel models, and their functions examined.
4) CO dehydrogenase: Synthesis and reactions of [Ni-4Fe-5S] active site model clusters will be examined, where preformed [3Fe-4S] clusters and sulfide-bridged Ni-Fe complexes are utilized.
5) [NiFe] hydrogenase: In addition to our reported oxidized state active site models, reduced state Ni-Fe dinuclear models are to be synthesized, and their reactions with H_2 or H^+ are to be investigated.
6) Unsymmetrical [4Fe-4S] clusters: The 1:3 site-differentiated [4Fe-4S] clusters modeling those found in [NiFe] hydrogenase and DPOR are to be synthesized.

Furthermore, we will expand the scope of bioinorganic chemistry in close cooperation with biochemistry, and will probe the ingenious functions of cluster active sites.

【Expected Research Achievements and Scientific Significance】

This research project is expected not only to bring about new foundations for our understanding the chemistry of enzymes, but also to create new chemistry concepts and environmentally-benign catalysts. For instance, the Haber-Bosch process to make ammonia are very energy-intensive, and 1-2% of the world's total energy output goes to ammonia synthesis. Thus, mimicking the function of nitrogenase would significantly impact the world's energy consumption. The research on the bio-inspired activation of H_2, H_2O, CO, and on bio-inspired synthesis of H_2 and O_2 from water will promote development of advanced science-based innovation and will contribute significantly to realizing a sustainable society.

【Publications Relevant to the Project】

[1]"Synthesis, Structures, and Electronic Properties of [8Fe-7S] Cluster Complexes Modeling the Nitrogenase P-Cluster", Y. Ohki, M. Imada, S. Ohta, and K. Tatsumi, *J. Am. Chem. Soc.*, **131**, 13168-13178 (2009).
[2] A Model for the CO-Inhibited Form of [NiFe] Hydrogenase: Synthesis of $(CO)_3Fe(\mu\text{-}S^tBu)_3Ni\{SC_6H_3\text{-}2,6\text{-}(mesityl)_2\}$ and Reversible CO Addition at the Ni Site. Y. Ohki, K. Yasumura, M. Ando, S. Shimokata, and K. Tatsumi, *Proc. Nat. Acad. Sci. ,USA*, *107*, 3994-3997 (2010).

【Term of Project】 FY2011-2015

【Budget Allocation】 309, 800 Thousand Yen

【Homepage Address and Other Contact Information】

http://inorg.chem.nagoya-u.ac.jp/e-frame.html

Title of Project : Creation of graphene terahertz lasers

Taiichi Otsuji
(Tohoku University, Research Institute of Electrical Communication, Professor)

Research Area : Engineering, Mathematical and physical sciences

Keyword : Lasers, Carbon materials, Electron devices, Quantum devices, Millimeter waves

【Purpose and Background of the Research】

Terahertz (THz), situated between light-waves and radio-waves, is one of the potential resources, but had long left as an unexplored band because of the luck of microelectronic technology that can generate/detect/ manipulate the electromagnetic waves over the entire THz range. The purpose of this research is to create a new type of graphene-based THz lasers. The current-injection-type THz lasing operation will be obtained even at room temperature by electrically induced p-i-n junction in our original dual-gate graphene-channel field effect transistor (FET) structure.

Graphene is a single-layer carbon-atomic honeycomb lattice crystal in which electrons/ holes hold a linear dispersion relation with zero bandgap and zero effective mass. Since its discovery by K. Novoselov and A. Geim in 2004, graphene has made a great impact on the academic and the industrial world. We have studied the nonequilibrium carrier relaxation/ recombination dynamics in optically/electrically pumped graphene and discovered the negative-dynamic conductivity in the THz range when pumping intensity beyond the threshold. Recently, we have succeeded in observation of an amplified stimulated emission of THz radiation from optically-pumped graphene.

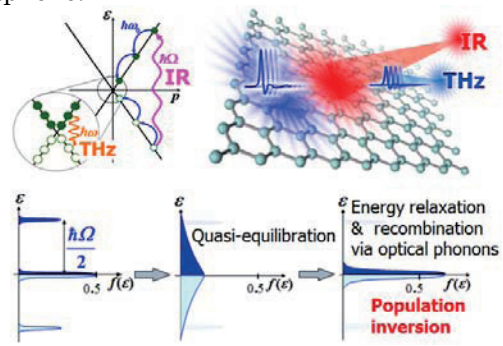


Fig. 1 Population inversion and stimulated THz emission from optically-pumped graphene.

【Research Methods】

The project will start to develop an optically-pumped graphene THz laser. We introduce a novel way to extremely gain the pumping efficiency by promoting the giant plasmon instabilities for the case of current injection-type laser realized in a dual-gate and/or dual-grating-gate FET structures. The final goal is to realize the world-first room-temperature current-injection-type THz lasing operation.

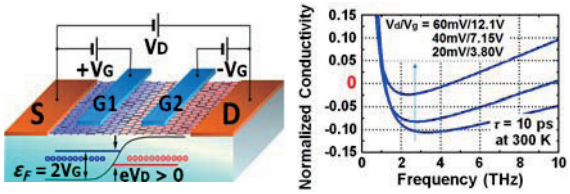


Fig. 2 Structure and simulated negative conductivity of a current-injection-type laser.

【Expected Research Achievements and Scientific Significance】

The birth of the new graphene laser theory is of extremely high scientific significance. The realization of world-first room-temperature operating integrated THz laser devices will give a tremendous impact to revolutionize industry paving the way to the future safe, secure and ubiquitous information and communication societies.

【Publications Relevant to the Project】

・V. Ryzhii, T. Otsuji, and M. Ryzhii, “Negative dynamic conductivity of graphene with optical pumping,” J. Appl. Phys. **101**, 083114 (2007).
・H. Karasawa, T. Komori, T. Watanabe, A. Satou, H. Fukidome, M. Suemitsu, V. Ryzhii, and T. Otsuji, "Observation of amplified stimulated terahertz emission from optically pumped heteroepitaxial graphene-on-silicon materials," J. Infrared Milli. Terahz. Waves, **32**, 655-665 (2011).

【Term of Project】 FY2011-2015

【Budget Allocation】 355,400 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.otsuji.riec.tohoku.ac.jp

Title of Project : Development of innovative water splitting photocatalysts based on photocarrier dynamics at solid/liquid interfaces

Kazunari Domen
(The University of Tokyo, Graduate School of Engineering, Professor)

Research Area : Catalyst/Resource chemical process, Functional materials

Keyword : Catalysis reaction, Photocatalyst, Surface/Interface

【Purpose and Background of the Research】

Hydrogen is the most convenient product from solar technology because it has a very high chemical energy, it can be used efficiently in fuel cells, and produces little pollution. We have developed the most highly active photocatalyst for overall water splitting under visible light irradiation in the world, which achieved a quantum yield of 5% at a wavelength of 410 nm. To achieve efficient one-step water splitting, an effective means of separation of photoexcited carriers and elucidation of the chemistry of energy conversion systems is required.

This project is aimed at the development of a photocatalytic system for one of the artificial photosynthesis systems for water splitting, to convert solar energy into chemical energy with unprecedented high efficiency. To address this objective, the precise analysis of the dynamics of photoexcited carriers and the surface reaction mechanisms will be performed. The goal of this project is the development of an innovative method to obtain practical photocatalysts for solar hydrogen production from water, on the basis of fundamental principles.

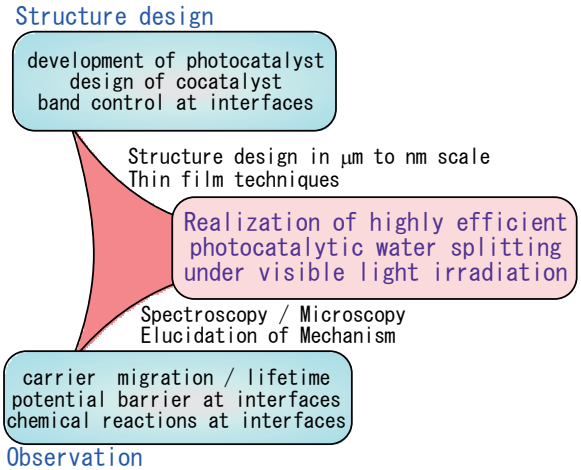


Fig. 1 Outline of this project

【Research Methods】

Topics in this project are as follows:

(1) improvement of the synthesis method of photocatalyst for shape and size control
(2) development of surface modifications
(3) *in-situ* analysis for nano-structures by spectroscopy and microscopy
(4) evaluation of carrier dynamics under irradiation by time-resolved spectroscopy

【Expected Research Achievements and Scientific Significance】

This project explores fundamental aspects of photcatalytic reactions focusing on photoexcited carrier dynamics, and covers the fields from solid state physics to surface chemistry. The development of water-splitting photocatalysts driven by solar radiation is likely to have a major impact both on basic science and society.

【Publications Relevant to the Project】

1) K. Maeda, T. Takata, M. Hara, N. Saito, Y. Inoue, H. Kobayashi, K. Domen, "GaN:ZnO Solid Solution as a Photocatalyst for Visible-Light-Driven Overall Water Splitting", *J. Am. Chem. Soc.*, **127**, 8286-8287, (2005).
2) K. Maeda, K. Teramura, D. Lu, T. Takata, N. Saito, Y. Inoue, K. Domen, "Photocatalyst releasing hydrogen from water - Enhancing catalytic performance holds promise for hydrogen production by water splitting in sunlight", *Nature*, **440**, 295, (2006).

【Term of Project】 FY2011-2015

【Budget Allocation】 410, 600 Thousand Yen

【 Homepage Address and Other Contact Information】

http://www.domen.t.u-tokyo.ac.jp/

Title of Project : Semiconductor Materials and Devices with Nonvolatile and Reconfigurable Functions

Masaaki Tanaka
(The University of Tokyo, Graduate School of Engineering, Professor)

Research Area : Applied materials science/Crystal engineering, Electronic materials
Keyword : spintronics, semiconductor, nonvolatile, reconfigurable

【Purpose and Background of the Research】

Semiconductor based materials with magnetic or spin-related properties can lead to new devices that use not only the charge of electrons and holes but also their spins. Fabricating such new materials and artificial nanostructures has been the fertile ground for novel functionalities, such as spin dependent transport, magnetoresistance, and magneto-optical effects.

For about twenty years, we have been studying ferromagnet / semiconductor heterostructures, III-V based magnetic semiconductor thin films and heterostructures, III-V / MnAs nano-composite structures, and devices using the spin degrees of freedom, including III-V based magnetic tunnel junctions, three terminal devices, spin MOSFETs and reconfigurable logic devices, and single-electron spin-transistors (SEST). In this project, based on these achievements, we aim at creating the following spintronic devices with nonvolatile memory and reconfigurable logic functions.

(1) III-V based magnetic tunnel junctions and heterojunction-type spin transistors
(2) Group-IV semiconductor based MOSFET-type spin transistors (spin MOSFETs)
(3) Magnetic tunnel junctions and single-electron spin transistors containing ferromagnetic nanoparticles.

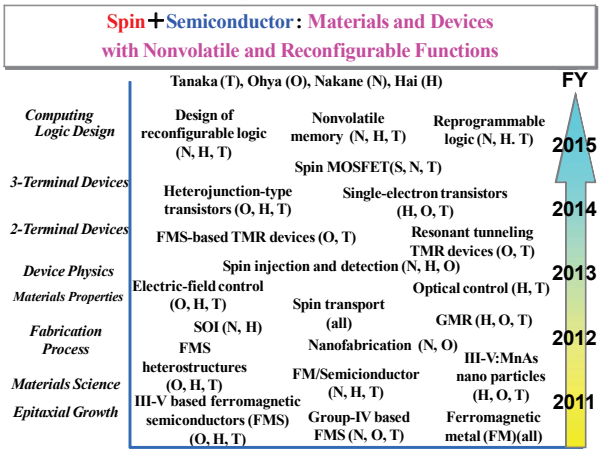


Figure 1 Research plan and schedule

【Research Methods】

Towards the applications to nonvolatile memory and reconfigurable logic, we carry out our research thoroughly from the material fabrication, understanding and control of the properties, physics of spin transport, device fabrication, and logic design. Principal and co-investigators work together following the plan shown in Fig. 1.

【Expected Research Achievements and Scientific Significance】

Spin transistors are potentially applicable to integrated circuits for ultrahigh-density nonvolatile memory whose memory cell is made of a single spin transistor and for nonvolatile reconfigurable logic based on the spin-dependent output of the spin transistors. The new devices and materials studied in this project will be able to give an impact on the future electronics industry.

【Publications Relevant to the Project】

・M. Tanaka and S. Sugahara, "Metal-Oxide-Semiconductor Based Spin Devices for Reconfigurable Logic", *Invited paper*, IEEE Transactions on Electron Devices Vol. **54**, pp.961-976 (2007).
・Pham Nam Hai, Shinobu Ohya, and Masaaki Tanaka, "Long spin-relaxation time in a single metal nanoparticle", Nature Nanotechnology **5**, pp.593-596 (2010).
・Shinobu Ohya, Kenta Takata, and Masaaki Tanaka, "Nearly non-magnetic valence band of the ferromagnetic semiconductor GaMnAs", Nature Physics **7**, pp.342-347 (2011).

【Term of Project】 FY2011-2015

【Budget Allocation】 414,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.cryst.t.u-tokyo.ac.jp/

【Grant-in-Aid for Specially Promoted Research】
Science and Engineering (Engineering)

Title of Project : Elucidation of adaptive lubrication mechanism with low friction and minimum wear in natural synovial joints and development of artificial hydrogel cartilage with super lubricity based on bionic design

Teruo Murakami
(Kyushu University, Faculty of Engineering, Professor)

Research Area : Biomedical engineering, Biomaterials, Biotribology

Keyword : Hydrogel artificial cartilage, Multimode lubrication in synovial joint, Artificial joints based on bionic design, Medical and biological engineering, Tribology

【Purpose and Background of the Research】

With growing elderly population, the number of arthritis patients is increasing. Applications of joint replacements to patients bring the recovery of walking ability and relief of severe pain. However, in certain cases, the revision operations are applied due to the loosening of joint prostheses which is usually derived form wear debris-induced osteolysis. To fully reduce wear in artificial joints, the development of hydrogel artificial cartilage with adaptive multimode lubrication mechanism has been conducted.

【Research Methods】

First, the detailed mechanism of multimode lubrication in natural synovial joints has been elucidated and subsequently those results will be applied to innovative artificial cartilage.

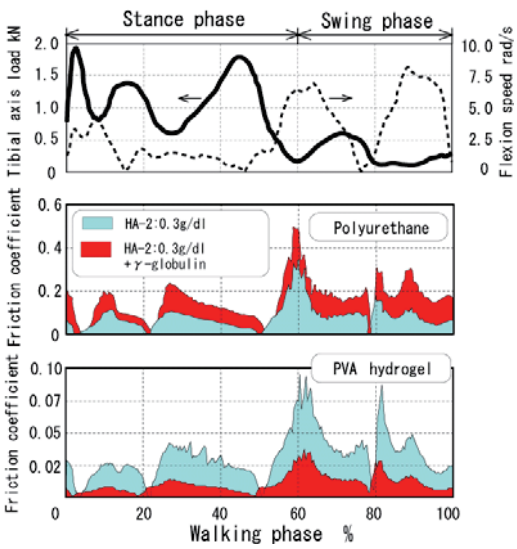


Fig.1 Frictional behavior of artificial cartilage (HA: Hyaluronic acid)

The frictional behaviors of simplified knee prostheses with soft layer during walking in Fig.1 indicated that PVA (poly(vinyl alcohol)) hydrogel with high water content showed very low friction compared with polyurethane layer. To extend the durability of joint prostheses, the establishment of optimum structure and properties for artificial cartilage as combination of repeated freezing-thawing and cast-dry methods for PVA hydrogel is planned. The collaboration of biomechanics, biotribology, biomaterials and biomedical fields is expected to produce superior artificial cartilage.

【Expected Research Achievements and Scientific Significance】

The establishment of clinical application of artificial cartilage with superior lubricity and longevity is expected. Exquisite devices with advanced hydrogel artificial cartilage will provide a leading guidance on bionic design.

【Publications Relevant to the Project】

(1) T. Murakami, K. Nakashima, Y. Sawae, N. Sakai and N. Hosoda, Roles of adsorbed film and gel layer in hydration lubrication for articular cartilage, Proc. IMechE, Part J, Journal of Engineering Tribology, Vol.223, No.3, 287-295, 2009
(2) K. Nakashima, Y. Sawae, T. Murakami, Influence of protein conformation on frictional properties of poly (vinyl alcohol) hydrogel for artificial cartilage, Tribology Letters, Vol.26, No.2, 145-151, 2007.
(3) E. Otsuka and A. Suzuki, A simple method to obtain a swollen PVA gel crosslinked by hydrogen bonds, Journal of Applied Polymer Science, Vol.114, No.1, 10-16, 2009.

【Term of Project】 FY2011-2015

【Budget Allocation】 348, 900 Thousand Yen

【Homepage Address and Other Contact Information】

http://biorc.mech.kyushu-u.ac.jp/SPR/index-en.html