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Annual Report 2014

Research Institute of Electrical Communication Tohoku University

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Annual report of Research Institute of Electrical Communication 2014

Contents

1. Introduction

Since the RIEC was established in 1935 based on the research of cutting-edge technologies such as Yagi-Uda antennas and magnetrons, a succession of pioneering achievements from RIEC have laid the foundations of information science and communications technology. Today, 80 years after it was established, the RIEC continues to play a world-leading role. In June we celebrated not only the institute's 80th anniversary but also the completion of construction of the main building, with its six floors, basement, and 13,513 square meters of total floor space. As much as we are pleased to have this new place of research, we are mindful of the words of then institute director Junichi Nishizawa at the institute's 50th anniversary celebration 30 years ago: "We must begin the study of a scientific discipline before the discipline has been given a name. This forms the basic spirit of the Research Institute of Electrical Communication as well as the Electrical Engineering Group, Tohoku University." Building on this tradition, we have geared our formidable research efforts toward the development and evolution of science and technology that enables the realization of communications that enrich people's lives.

For this purpose, the institute since 2004 has been organized into three units: four research divisions (Information Devices Division, Broadband Engineering Division, Human Information Systems Devision, and Systems & Software Devision), two laboratories (Laboratory for Nanoelectronics and Spintronics, and Laboratory for Brainware Systems), and the Research Center for 21st Century Information Technology. These units are engaged in research aimed at achieving fruition over different time scales (Research Divisions: 20 years, Laboratories: 10 years, Research Center: 5 years). We have entered into close cooperation with Tohoku University's graduate schools in subjects relating to electrical engineering (School of Engineering, Graduate School of Information Sciences and Graduate School of Biomedical Engineering) in order to cover a wide range of cutting-edge research fields and foster the development of highly educated researchers and engineers.

In 2010, the RIEC was certified by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) as a Joint Usage/Research Center for collaborative research in information science and technology. To contribute to further community development, we are working on joint research projects with external researchers and engineers from industry, government and academia.

Today, information science and technology is an essential part of the social infrastructure, and there are

growing demands for the implementation of faster higher-capacity telecommunications with greater energy savings. Another key attribute of the social infrastructure is disaster tolerance; a requirement that was demonstrated only too well by the impact of the Great East Japan Earthquake of 2011. We also expect to contribute to a new paradigm of information processing and communication that interconnects people in a fundamentally different way. At the RIEC, we will continue to address these social needs by taking full advantage of our status as a university-affiliated research center. In this way, we hope to play a leading role in the new world of communication, and thereby promote education in the future.

To contribute to the improvement of our research activities and support future developments, we have published this Annual Report every year to make our activities relating to research, education and social contribution widely available for public scrutiny. This edition contains reports on various activities including the research at each of our departments and laboratories, the RIEC symposium, nation-wide cooperative research projects, and the activities of the engineering research association and RIEC lectures. In addition, the bibliography section has been greatly enhanced compared with last year's edition, and now carries the data for various activities over the last five years.

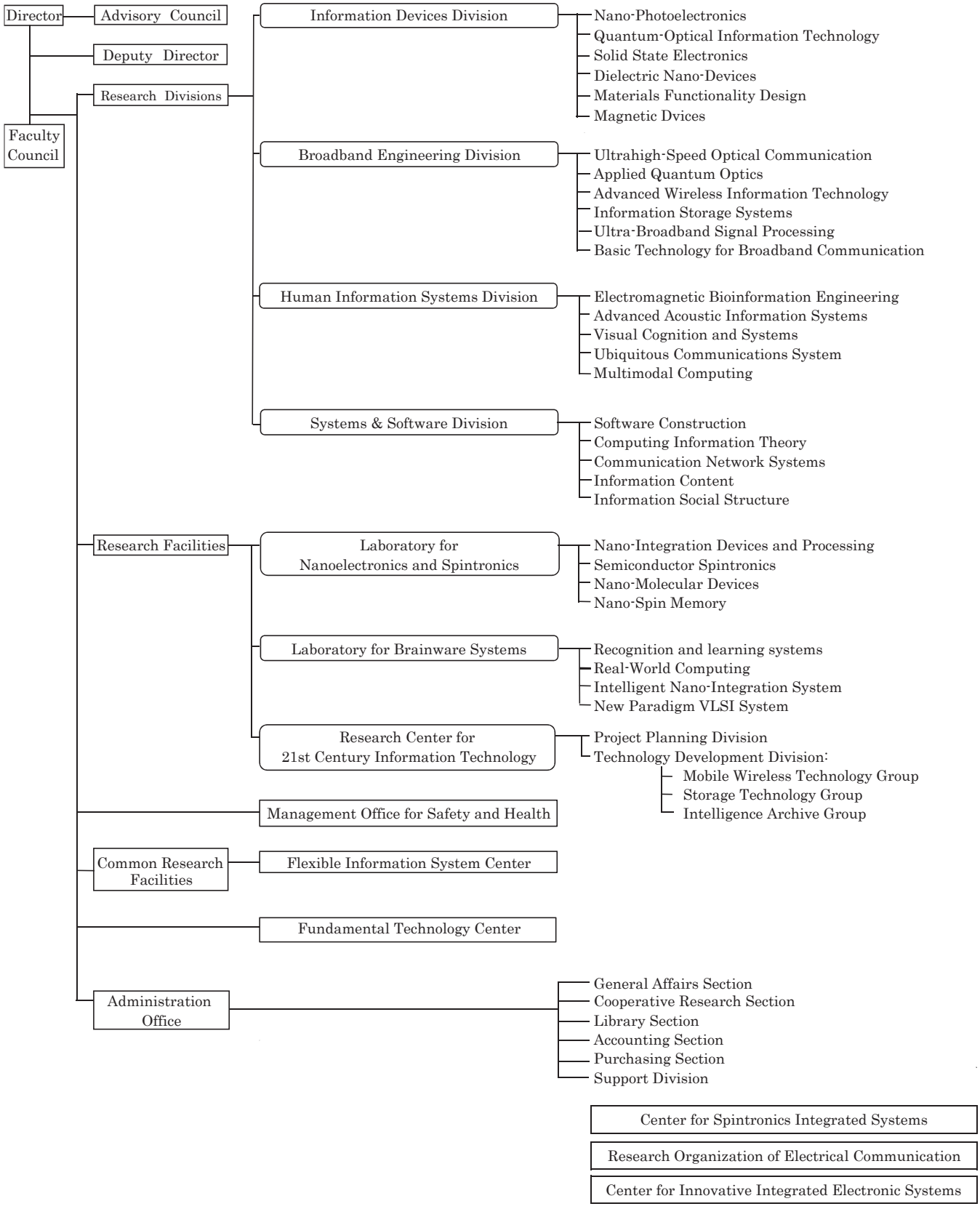
We welcome your frank opinions regarding our research reports, and I sincerely hope we can continue to rely on your guidance and support in the future.

May 1, 2015

Director, Research Institute of Electrical Communication

Hideo Ohno

2. Organization Chart



3. Research Activities

Targets and achievements of the Information Devices Division

The main aim of the information devices division is to create new materials and devices for next generation communication technology.

To accomplish this goal, we have the following 6 sub-divisions. The research fields include nano-scale photoelectronic conversions, quantum-optical information technology, novel transport properties in low-dimensional systems, new dielectrics-based nano-devices for information storage, and design of new materials having exotic functionalities. We also have a partnership with *Nano-Integration Devices and Processing* section in the Laboratory for Nanoelectronics and Spintronics.

1. Nano-Photoelectronics
2. Quantum-Optical Information Technology
3. Solid State Electronics
4. Dielectric Nano-Devices
5. Materials Functionality Design
6. Magnetic Devices (Visitor Section)

The research target and the summary of activities of each sub-division in 2014 are described in the following pages. The summary of activities of *Nano-Integration Devices and Processing* section is described in the chapter of Laboratory for Nanoelectronics and Spintronics.

Nanophotoelectronics

Exploring optical and electronic properties of nanometer-sized structures and their applications in photoelectronic devices

Nanophotoelectronics Yoichi Uehara, Professor
Nano photomolecular electronics Satoshi Katano, Associate Professor

[Research Target and Activities]

Our main interest lies in studying the physical and chemical phenomena that take place in nanometer-scale regions and their applications in nanophotoelectronic devices. We investigate the material properties of nanostructures through their optical responses to the local excitation induced by electrons from the tip of a scanning tunneling microscope (STM), as illustrated in Fig. 1.

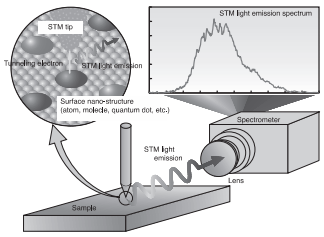


Fig. 1 STM light emission spectroscopy.

STM light emission spectra of Sb_2Te_3 were measured in the configuration that the tip-sample gap of the STM is irradiated by a pair of pump and probe laser pulses with a duration less than 2 ps each, and were analyzed as a function of optical delay time between the pump and probe pulses. We found that the peak energy of the STM light emission, which is excited via electronic transitions of Sb_2Te_3, is shifted toward the higher energy side when the optical delay time is in the range between around 2 ps to 13 ps. This result demonstrates that the proposed method has temporal resolution of ps.

Fluorescence and quenching of light from graphene oxide (GO) have been extensively investigated due not only to the basic interests but also to the technological applications, such as transparent conductors and biosensors. In this year, we carried out the nano-scale observation of GO on Au(111) covered with the self-assembled monolayer (SAM) as a first step towards revealing the local electronic states of GO. In the STM image of GO, we clearly identified the single GO layer with the thickness of 0.8 nm. We found that the bandgap value varies depending on the location of the STS measurement, reflecting the nano-scale heterogeneity of sp^2 domain in GO.

[Staff]

Professor	Yoichi Uehara, Dr.
Associate Professor	Satoshi Katano, Dr.

[Profile]

Dr. Yoichi Uehara obtained his D. Eng. degree from the Department of Engineering, University of Osaka prefecture in 1986, after which, he was initially appointed as an Assistant Professor at the Research Institute of Electrical Communication, Tohoku University. He eventually became a Full Professor at the institute in 2005. Dr. Uehara has worked on three main surface physics problems at Tohoku University: (1) light emission from metal-insulator-metal and metal-oxide-semiconductor (MOS) tunnel junctions, (2) low-energy electron spectroscopy, and (3) light emission spectroscopy of STM.

Dr. Satoshi Katano received his D. Sci. degree from Department of Electronic Chemistry, Tokyo Institute of Technology in 2003. He was a postdoctoral research fellow in RIKEN (2003-2006). He joined RIEC, Tohoku University as an assistant Professor in 2006 and was promoted to an associate Professor in 2012. His research interests include surface physical chemistry and nano-scale molecular optoelectronics.

[Papers]

[1] Y. Uehara, M. Kuwahara, and S. Katano, "Measurement of Phonon Energy of Sb_2Te_3 by Scanning Tunneling Microscope Light-emission Spectroscopy", *Solid State Commun.*, **177**, 29-32 (2014).
[2] Y. Uehara, S. Katano, M. Kuwahara, and T. Suzuki, "Electromagnetic effects of STM tip–sample gap in the THz spectral range", *22nd International Colloquium on Scanning Probe Microscopy*, Atagawa Heights, Japan (2014).
[3] S. Katano, Y. Kim, M. Kawai, and M. Trenary, "Surface Hydrogenation Reactions at the Single-Molecule Level", *Chem. Rec.*, **14**, 819-826 (2014).

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Quantum-Optical Information Technology

Development of optoelectronic devices for quantum information and communication technology

Quantum-Optical Information Technology: Keiichi Edamatsu, Professor
Quantum Laser Spectroscopy: Yasuyoshi Mitsumori, Associate professor

[Research Target and Activities]

Our goal is to develop the quantum information devices utilizing quantum interaction between photons and electrons in solids. In 2013, we have achieved (1) experimental demonstration of error-disturbance uncertainty relations in photon polarization measurement, (2) observation of local-field effects on optical coherent transients of semiconductor quantum dots.

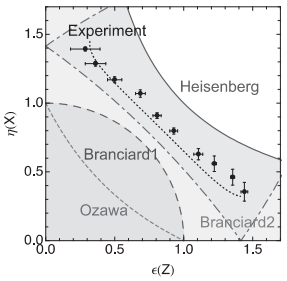


Fig. 1 Experimental results (filled circles) and predicted lower bounds (curves) of error-disturbance uncertainty relations (EDR) in photon polarization measurement. The Heisenberg EDR (blue) is violated while the EDRs proposed by Ozawa (red) and Branciard (purple and green) hold.

[Staff]

Professor: Keiichi Edamatsu, Dr.
Associate Professor: Yasuyoshi Mitsumori, Dr.

[Profile]

Keiichi Edamatsu received B.S., M.S., and D.S. degrees in Physics from Tohoku University. He was a Research Associate in Faculty of Engineering, Tohoku University, a Visiting Associate in California Institute of Technology, and an Associate Professor in Graduate School of Engineering Science, Osaka University.

Yasuyoshi Mitsumori received B.S., M.S. and D.S. degrees in Applied Physics from Tokyo Institute of Technology. He was a Research Fellow of the Japan Society for the Promotion of Science, a Researcher in NTT Basic Research Laboratories, a Postdoctoral Fellow in Tokyo Institute of Technology, a Postdoctoral Fellow in Communications Research Laboratory, a Research Associate in Research Institute of Electrical Communication, Tohoku University.

[Papers]

[1] K. Edamatsu, “A shy quantum’s uncertainty relation”, Oyo Butsuri (in Japanese) **83**, No.5, 390-393 (2014).
[2] K. Edamatsu, “Polarization quantum bits and entanglement -photon polarization and quantum information-”, Optical Alliance (in Japanese) **25**, No.11, 1-5 (2014).
[3] K Edamatsu, F. Kaneda, So-Young Baek, and M. Ozawa, “Experimental test of error, disturbance, and uncertainty relations in quantum measurement”, Butsuri (in Japanese) **70**, No. 3, 188-193 (2015).

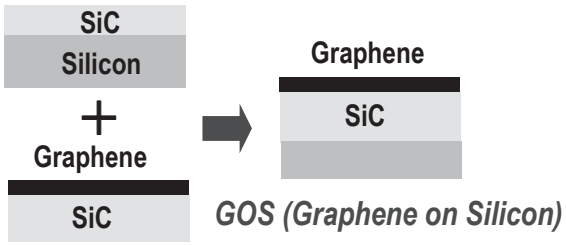
Solid State Electronics Laboratory

Paving a Way for Introducing Graphene into Silicon Technology

Solid State Electroncis　Maki Suemitsu, Professor
Solid State Physics for Electroncis　Hirokazu Fukidome, Associate Professor

[Research Target and Activities]

Graphene is a two-dimensional honeycomb network of carbon atoms. Its extremely high carrier mobility, which is ~100 times as high as that of silicon, makes graphene a dream material. We have developed a method to form an epitaxial graphene onto silicon substrates for the first time by growing a heteroepitaxial SiC thin film on a Si substrate and by sublimating the surface Si atoms from the SiC film (graphene-on-Si, or GOS, technology). We are currently working on the clarification of the growth kinetics of the epitaxial graphene formation in GOS as well as on the development of graphene devices such as gas sensors, digital and RF field-effect transistors, and optical devices using the GOS structure.



In FY2014, we have developed several methods to improve the 3C-SiC and epitaxial graphene films on SiC crystals as well as operando analysis to characterize them.

[Staff]

Professor : Maki Suemitsu, Dr.
Assistant Professor : Hirokazu Fukidome, Dr.
Visiting Professor : Hiroyuki Nagasawa, Dr.
Research Assistant : Sai Jiao, Dr.
Research Assistant: Venugopal Gunasekaran
Technical Assistant : Kumi Namiiri

[Profile]

Prof. Maki Suemitsu received Ph.D on electronic engineering from Tohoku University in 1980. He started his service at Research Institute of Electrical Communication (RIEC) in 1980, became associate professor in 1990, and became professor at Center for Inderdisciplinary Research, Tohoku University in 2003. Since 2008, he has been professor at RIEC. He has been engaged mainly on surfaces of semiconductor thin fims. He was awarded the 30 th Kumagai prize of the best paper from the Vacuum Soceity of Japan (2005) and the Best Paper Award from the Surface Science Society of Japan (2011).

Prof. Hirokazu Fukidome received Ph.D on chemistry from Osaka University. After serving for Bell Labs and RIKEN, he became assistant professor at RIEC in 2008. He has been associate professor at RIEC since 2012. He has been engaged on two-dimensional Dirac electron systems and their operando-microscopy analysis. He was awarded the Best Paper Award from the Surface Science Society of Japan (2011).

[Papers]

[1] Hirokazu Fukidome, …, Maki Suemitsu, "Microscopically-tuned band structure of epitaxial graphene through interface and stacking variations using Si substrate microfabrication," Scientific Reports, 4, pp 5173-1-6, 2014.
[2] Maki Suemitsu, Sai Jiao, Hirokazu Fukidome, Yasunori Tateno, Isao Makabe, Takashi Nakabayashi, "Epitaxial graphene formation on 3C-SiC/Si thin films," Journal of Physics D: Applied Physics, 47, pp. 094016-1-11, 2014.
[3] H. Fukidome, M. Kotsugi, K. Nagashio, M. Suemitsu, T. Kinoshita, "Orbital-specific tunability of many-body effects in bilayer graphene by gate bias and metal contact," Scientific Reports, 4, pp. 3713-1-5, 2014.

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Dielectric Nano-Devices

Research on Dielectric Nano Science and Technology

Dielectric Nano-Devices Yasuo CHO, Professor

[Research Target and Activities]

Our main area of interest is evaluation and development of dielectric materials, including ferroelectric and piezoelectric materials and their application to communication devices and ferroelectric data storage systems. Our major contributions to advancement in these fields are the invention and the development of "Scanning Nonlinear Dielectric Microscope" (SNDM) which is the first successful purely electrical method for observing the ferroelectric polarization distribution without the influence of the shielding effect by free charges and it has already been put into practical use. The resolution of the microscope has been improved up to atomic scale-order. Therefore, it has a great potential for realizing the ultra-high density ferroelectric recording system.

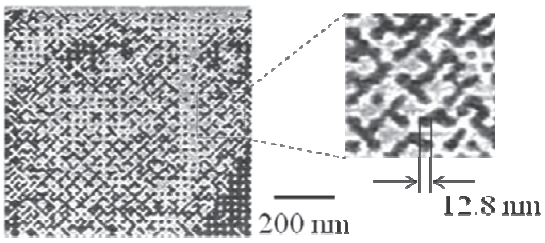

Fig.1 Digital bit data written on ferroelectric single crystal with the areal recording density of 4 Tbit/inch^2.

Major achievements of studies in 2014 are as follows: (1) Si(100) 2×1 surface and hydrogen-intercalated graphene on 4H-SiC(0001) surface were observed using noncontact scanning nonlinear dielectric microscopy (NC-SNDM) with an atomic resolution. Additionally, surface potential distribution image of Si(111) 7×7 surface was obtained with an atomic resolution. (2) Dopant profiles of SiC MOS devices were obtained using super-higher-order nonlinear dielectric microscopy. Additionally, dopant profile observation of amorphous Si solar cell devices was also achieved. (3) In the development of a ferroelectric data storage technology, dot array writing using HDD-type test system was demonstrated. The recording density reached 3.4 Tbit/inch^2. Additionally, improvement for PZT film media by ion beam radiation was reported.

[Staff]

Professor : Yasuo Cho, Dr.
Assistant Professor : Yoshiomi Hiranaga, Dr.
Assistant Professor : Kohei Yamasue, Dr.
Technical Official : Yasuo Wagatsuma

[Profile]

Yasuo Cho graduated in 1980 from Tohoku University in electrical engineering department. In 1985 he became a research associate at Research Institute of Electrical Communication Tohoku University. In 1990, he received an associate professorship from Yamaguchi University. He then became an associate professor in 1997 and a full professor in 2001 at Research Institute of Electrical Communication Tohoku University. During this time, his main research interests included nonlinear phenomena in ferroelectric materials and their applications, research on the scanning nonlinear dielectric microscope, and research on using the nonlinear dielectric microscope in next-generation ultrahigh density ferroelectric data storage (SNDM ferroelectric probe memory).

[Papers]

[1] N. Chinone, T. Nakamura, and Y. Cho, "Cross-sectional dopant profiling and depletion layer visualization of SiC power double diffused metal-oxide-semiconductor field effect transistor using super-higher-order nonlinear dielectric microscopy", J. Appl. Phys, Vol. 116, p.084509, 2014

[2] K. Yamasue, M. Abe, Y. Sugimoto and Y. Cho, "Atomic-dipole-moment induced local surface potential on Si(111)-(7×7) surface studied by non-contact scanning nonlinear dielectric microscopy", Appl. Phys. Lett. Vol. 105, p. 121601, 2014

[3] Y. Hiranaga and Y. Cho, "Pb (Zr, Ti)O_3 recording media for probe data storage devices prepared by rf magnetron sputtering", Jpn. J. Appl. Phys, vol.53, p.09PA05, 2014

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Materials Functionality Design

Computational Design of Functional Materials for Spintornics Devices

Materials Functionality Design: Masafumi Shirai, Professor

[Research Target and Activities]

Our research targets are as follows: (1) theoretical analyses of quantum phenomena which appear in materials and nanostructures for advanced information devices, (2) computational design of materials and nanostructures which possess new functionalities for improvement of device performance, and (3) development of new design procedures based on large-scale computational simulation techniques.

Our research activities in FY 2013 are as follows:

(1) Transport in magnetic tunnel junctions

We investigated the magnetic properties of $L1_0$-FeNi alloy doped with light elements by using the first-principles calculation. The uniaxial magnetic anisotropy energy K_u is enhanced by doping of B, C or N at an octahedral interstitial site. By the 2.6 at% C-doping, K_u increased from 5.5 MJ/m^3 for undoped FeNi to 9.8 MJ/m^3 (Fig. 1). The enhancement of K_u is related to the increased number of Fe 3*d* electrons by the doping.

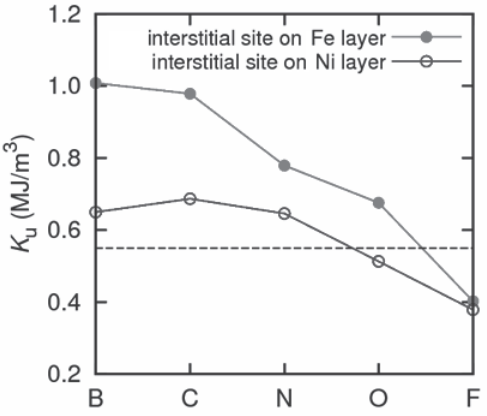

Fig. 1

(2) Detection of spin-resolved electronic structures

We successfully detected spin-resolved electronic structure of a buried ferromagnetic film. Utilizing the forward Mott scattering in Au capping layer on the ferromagnetic film, we can resolve the spins of photoelectrons efficiently without using any standard spin detectors. This method enables us to measure the spin-resolved electronic structure in spintornics devices [1].

[Staff]

Professor: Masafumi Shirai, Dr.
Assistant Professor: Kazutaka Abe, Dr.
Assistant Professor: Masahito Tsujikawa, Dr.

[Profile]

Masafumi Shirai received the Doctor of Engineering degree from Osaka University in 1989. From 1988 to 1996, he was a Research Associate, and then, from 1996 to 2002, an Associate Professor at Osaka University. From 2002 to the present, he has been a Professor at Tohoku University. Now his research interest is focused on computational design of functional materials for spintronics devices.

[Papers]

[1] S. Ueda, M. Mizuguchi, T. Kojima, S. Ishimaru, M. Tsujikawa, M. Shirai, and K. Takanashi, "Detection of spin-resolved electronic structures from a buried ferromagnetic layer utilizing forward Mott scattering," Appl. Phys. Lett., Vol. 104, No. 13, Article No. 132402, pp.1-5, 2014

[2] H. Nishihara, K. Suzuki, R. Y. Umetsu, T. Kanomata, T. Kaneko, M. Y. Zhou, M. Tsujikawa, M. Shirai, T. Sakon, T. Wada, K. Terashima, and S. Imada, "Magnetic properties of Ni_2N," Physica B, Vol. 449, pp.85-89, 2014

[3] S. Kanai, M. Tsujikawa, Y. Miura, M. Shirai, F. Matsukura, and H. Ohno, "Magnetic anisotropy in Ta/CoFeB/MgO investigated by x-ray magnetic circular dichroism and first-principles calculation," Appl. Phys. Lett., Vol. 105, No. 22, Article No. 222409, pp.1-4, 2014

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Broadband Engineering Division: Research Target and Results

In order to establish the future broadband communication systems and novel devices that are flexibly applied to the future ubiquitous ultra-large capacity information communication, research and development are carrying out over the wide bands of microwaves, millimeter/submillimeter waves, terahertz waves, and lightwaves with regard to the information generation, transmission, processing, and storage technologies.

(1) Advanced Wireless Information Technology

We are actively engaged in the research work on the dependable wireless information technologies for the next generation wireless systems which include terrestrial / satellite communications. We cover the whole technical fields from the lower to higher layers, i.e., signal processing, RF/Mixed signal device, antenna, MODEM and network technologies. We have developed network selection scheme using map based on communication quality and positioning information for heterogeneous wireless system. A concept of "Traffic-navigation" has been proposed by using that scheme. We have also developed RF-IC and modules such as sample-hold circuit and phased array module for high speed wireless communication systems.

(2) Ultra-Broadband Signal Processing

We are developing novel, integrated electron devices and circuit systems operating in the terahertz region. One of our major concerns is a new material called "graphene", a single-layered honeycomb-lattice carbon crystal.

First, we theoretically discovered and experimentally verified the giant THz gain of the surface plasmon polaritons in population-inverted graphene. We also experimentally verified the amplified-spontaneous and stimulated THz emission in optically pumped graphene at room temperature. Second, we developed plasmon-resonant THz emitters/detectors, verifying the validity of the physical modeling for the frequency dependence of the detection sensitivity by using experimental results including the record-breaking sensitivity at room temperature.

(3) Ultrahigh-Speed Optical Communication

To achieve a global high-capacity optical network, we have been engaging in the research on ultrahigh-speed Optical Time-Division Multiplexing (OTDM) transmission and highly spectral-efficient coherent Quadrature Amplitude Modulation (QAM) transmission.

This year, we newly proposed a time-domain orthogonal TDM transmission, in which optical Nyquist pulses are transmitted and demultiplexed by a homodyne

detection with a phase-locked synchronous Nyquist LO pulse. By adopting this scheme, we succeeded in 1.92 Tbit/s/ch transmission with a spectral efficiency as high as 10.6 bit/s/Hz. We also proposed a simple and highly-precise injection-locked homodyne detection circuit for coherent QAM signals, which was successfully applied to a 256 QAM transmission.

(4) Applied Quantum Optics

Novel functional semiconductor photonic devices including photonic integrated circuits are being investigated to explore new-generation photonic network systems.

The study on cross gain modulation (XGM) laser with external cavity is being continued. It was confirmed that the laser source can be operated up to 80 GHz. The study on compact and narrow linewidth semiconductor laser sources is also being proceeded. A compact and simple optical negative feedback scheme was proposed which need only an optical filter. By applying the scheme to a semiconductor laser, it was confirmed experimentally that the spectral linewidth of the laser was able to be reduced to 6 kHz (1/1,000). Furthermore, the study on a flat-top optical frequency comb block generation is being carried out by using a semiconductor Mach-Zehnder modulator (InP-MZM). It was confirmed that very flat (< 0.5 dB) 9-ch optical frequency comb was able to be generated by using the modulator.

(5) Information Storage Systems

Research on next-generation perpendicular magnetic recording is carrying out for high density data storage to meet the strong demand of rapid information increase in the Internet, and storage system technology as well.

We unveil that areal density of 5 Tbit/inch^2, which is five times of the current density, is achieved by the bit-patterned media in association with thermal assist recording technique that heats a narrow recording area. High areal densities are possible with a novel media whose grain location is somewhat controlled. Storage system technology to enhance the data transfer rate was also developed. A Two-Dimensional-Magnetic-Recording was investigated to read two tracks simultaneously to double the data transfer rate.

Research Laboratory of Ultrahigh-Speed Optical Communication

Advanced optical communication technologies approaching the Shannon limit

Research Area of Optical Transmission Masataka Nakazawa, Professor
Research Area of Optical Signal Processing Toshihiko Hirooka, Associate Professor
Research Area of High Accuracy Measurements using Optical Fibers
Masato Yoshida, Associate Professor

[Research Target and Activities]

With the vast growth of Internet traffic, it has become increasingly important to realize a high-capacity and high-speed network. This laboratory aims to achieve a global ultrahigh-speed optical network by engaging in the research of ultrashort pulse and coherent transmission. This year, we newly proposed a time-domain orthogonal TDM transmission, in which optical Nyquist pulses are transmitted and demultiplexed by a homodyne detection with a phase-locked synchronous Nyquist LO pulse. By adopting this scheme, we succeeded in 1.92 Tbit/s/ch, 64 QAM transmission over 150 km within a bandwidth of 170 GHz, resulting in a spectral efficiency as high as 10.6 bit/s/Hz.

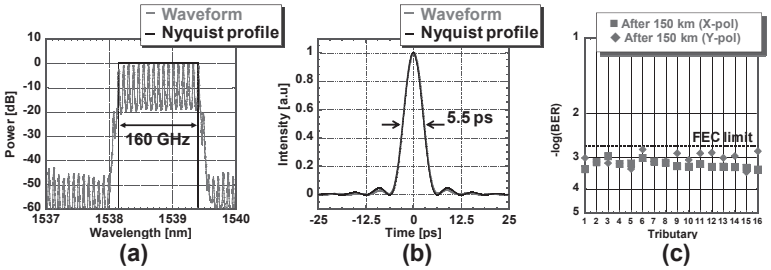

Fig. 1 Spectrum (a) and waveform (b) of a coherent Nyquist pulse and (c) 1.92 Tbit/s, 64 QAM-150 km transmission result.

[Staff]

Distinguished Professor: Masataka Nakazawa, Dr. Associate Professor: Toshihiko Hirooka, Dr.
Associate Professor: Masato Yoshida, Dr. Assistant Professor: Keisuke Kasai, Dr.

[Profile]

Masataka Nakazawa received the Ph. D. degree from the Tokyo Institute of Technology in 1980. He joined the Ibaraki Electrical Communication Laboratory, Nippon Telegraph & Telephone Public Corporation. He was a visiting scientist at MIT in 1984-1985. In 2001, he became a Professor of the Research Institute of Electrical Communication, Tohoku University, where he has been engaged in research on ultrahigh-speed optical communication including soliton transmission, nonlinear effects in fibers, mode-locked lasers, and photonic crystal fibers. He is currently the Director of Research Organization of Electrical Communication.

Toshihiko Hirooka received the Ph. D. degree from Osaka University in 2000. From 2000 to 2002, he was a Research Associate at University of Colorado at Boulder. He is currently an Associate Professor at the Research Institute of Electrical Communication, Tohoku University. He has been engaged in research on ultrahigh-speed optical communications and nonlinear fiber optics.

Masato Yoshida received the Ph.D. degree from Tohoku University in 2001. In 2001, he joined the Research Institute of Electrical Communication, Tohoku University, where he is currently an Associate Professor. His research interests include mode-locked fiber lasers, coherent optical communication, and photonic crystal fibers.

[Papers]

[1] M. Nakazawa, M. Yoshida, and T. Hirooka, “The Nyquist laser,” Optica vol. 1, no. 1, pp. 15-22, July (2014).
[2] K. Harako, D. O. Otuya, K. Kasai, T. Hirooka, and M. Nakazawa, “High-performance TDM demultiplexing of coherent Nyquist pulses using time-domain orthogonality,” Opt. Express, vol. 22, no. 24, pp. 29456–29464, December (2014).
[3] S. Beppu, K. Kasai, M. Yoshida, and M. Nakazawa, "2048 QAM (66 Gbit/s) single-carrier coherent optical transmission over 150 km with a potential SE of 15.3 bit/s/Hz," Opt. Express, vol. 23, no. 4, pp. 4960-4969, February (2015).

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Applied Quantum Optics

Research on Innovative Highly Functional Photonic Semiconductor Devices

Highly Functional Photonics Hiroshi Yasaka, Professor

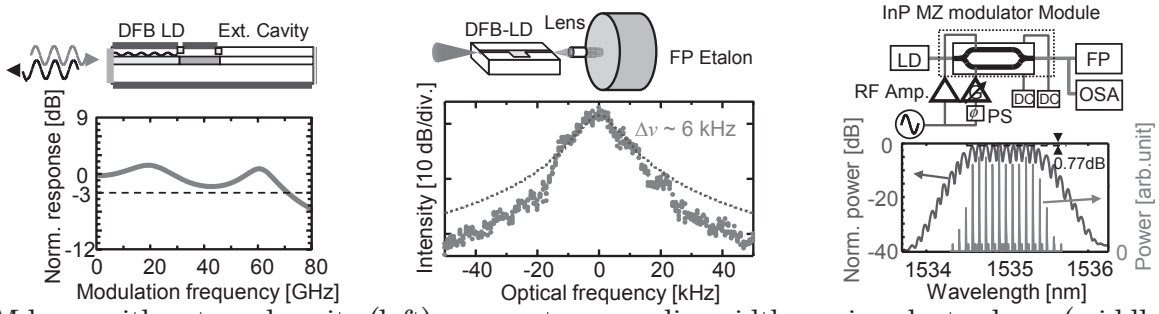
[Research Target and Activities]

Novel functional semiconductor photonic devices including InP-based photonic integrated circuits are being investigated to explore new-generation photonic network systems.

The study on cross gain modulation (XGM) laser with external cavity is being continued. It was confirmed that the laser source can be operated up to 80 GHz, and 3-dB bandwidth wider than 40 GHz was measured experimentally by using a fabricated device.

The study on compact and narrow linewidth semiconductor laser sources is also being proceeded. A compact and simple optical negative feedback scheme was proposed which need only an optical filter. By applying the scheme to a semiconductor laser, it was confirmed experimentally that the spectral linewidth of the laser was able to be reduced from 6 MHz to 6 kHz.

Furthermore, the study on a flat-top optical frequency comb block generation is being carried out by using a semiconductor Mach-Zehnder modulator (InP-MZM). It was confirmed that very flat (< 0.5 dB) 9-ch optical frequency comb was able to be generated by using the modulator.



XGM laser with external cavity (left), compact narrow linewidth semiconductor laser (middle), and flat optical frequency comb generation with InP-MZM (right).

[Staff]

Professor : Hiroshi Yasaka, Dr.
Assistant Professor : Nobuhide Yokota, Dr.

[Profile]

Hiroshi Yasaka received M.S. degrees in physics from Kyusyu University in 1985, and Ph.D. degree in electronic engineering from Hokkaido University in 1993. In 1985 he joined Nippon Telegraph and Telephone (NTT) Corporation. Since then, he has been engaging in research and development on semiconductor photonic devices for optical fiber communication systems. From 2008 he has been a professor of Tohoku University.

[Papers]

[1] S. Mieda, S. Shiratori, N. Yokota, W. Kobayashi, and H. Yasaka, "Ultra-high-speed Operation of Laser Diode with External Cavity by Cross-gain Modulation," Applied Physics Express, vol. 8, No. 2, 022701, 2015 (Feb.) - DOI 10.7567/APEX.8.022701

[2] K. Aoyama, R. Yoshioka, N. Yokota, W. Kobayashi, and H. Yasaka, "Experimental demonstration of linewidth reduction of laser diode by compact coherent optical negative feedback system," Applied Physics Express, vol. 7, No. 12, 122701, 2014. (Dec.) - DOI 10.7567/APEX.7.122701

[3] K. Aoyama, R. Yoshioka, N. Yokota, W. Kobayashi, and H. Yasaka, "Optical Negative Feedback for Linewidth Reduction of Semiconductor Lasers," IEEE Photonics Technology Letters, vol. 27, No. 4, pp. 340-343, 2015. (Feb.) - DOI 10.1109/LPT.2014.2371074

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Advanced Wireless Information Technology

For realization of the next generation mobile network

Advanced Wireless Information Technology **Noriharu Suematsu, Professor**
Advanced Wireless Network Technology **Suguru Kameda, Associate Professor**

[Research Target and Activities]

Toward the realization of a ubiquitous and broad-band wireless network, we are actively engaged in the research work on dependable and low power consumption advanced wireless IT. We cover the whole technical fields from the lower to higher layers, i.e., signal processing, RF/Mixed signal device, antenna, MODEM and network technologies.

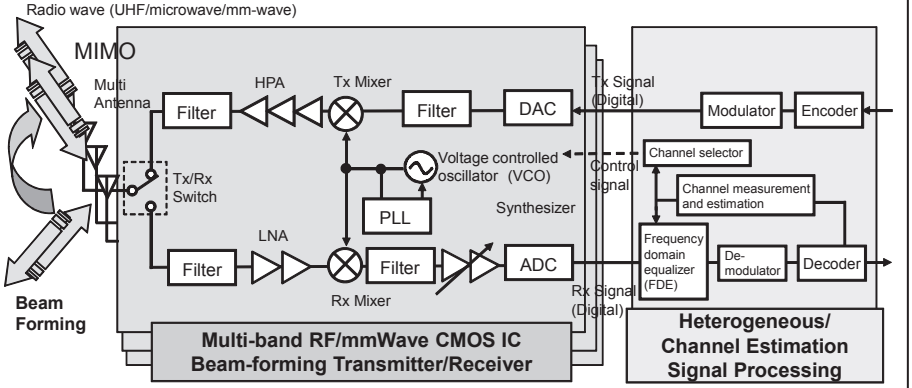

Fig. The target system of
Advanced Wireless Information Technology Laboratory.

We have developed network selection scheme using map based on communication quality and positioning information for heterogeneous wireless system. And, we propose the Traffic-navigation by using these scheme. We have also developed RF-IC and modules like sample-hold circuit and phased array module for high speed and wideband wireless communication system.

[Staff]

Professor: Noriharu Suematsu, Ph. D
Associate Professor: Suguru Kameda, Ph. D
Assistant Professor: Mizuki Motoyoshi, Ph.D

[Profile]

Noriharu Suematsu received the M.S. and Ph.D. degrees in Electronics and Communication Engineering from Waseda University in 1987 and 2000. From 1987 to 2010, he had been with the R&D center of Mitsubishi Electric, Japan. Since 2010, he has been a professor of Research Institute of Electrical Communication (RIEC), Tohoku University. He received the OHM technology award from the promotion foundation for electrical science and engineering in 2002 and Prize for Science and Technology, the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology in 2009.

Suguru Kameda received the B.S., M.S. and Ph.D. degrees in Electronics Engineering from Tohoku University in 1997, 1999 and 2001, respectively. From 2001, he was an assistant professor of the RIEC. From 2012, he has been currently an associate professor.

[Papers]

[1] N. Suematsu, *et al.*, ""A 60-GHz-Band 2 x 4 Planar Dipole Array Antenna Module Fabricated by 3-D SiP Technology," IOP Conf. Series: Materials Science and Engineering, 61 (2014) 012036 (Invited).
[2] S. Kameda, *et al.*, "Development of Satellite-Terrestrial Multi-Mode VSAT Using Software Defined Radio Technology," 2014 Asia-Pacific Microwave Conference (APMC2014), TH1A-5, Nov. 2014.
[3] N. Suematsu *et al.*, "Multi-Mode Portable VSAT for Disaster-Resilient Wireless Networks," 2014 Asia-Pacific Microwave Conference (APMC2014), TH2E-4, Nov. 2014 (Invited).

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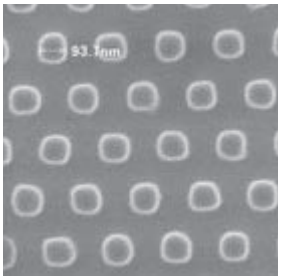
Information Storage System

Research on Large Capacity Information Storage System using High Density Perpendicular Magnetic Recording

Information Storage Systems: Hiroaki Muraoka, Professor
Recording Theory Computation: Simon J. Greaves, Associate Professor

[Research Target and Activities]



The amount of digital information is rapidly growing year by year, and is estimated to reach to Zata-byte in 2020. For such extremely large storage capacity high density magnetic recording is required. Next-generation perpendicular magnetic recording is explored in order to continuously develop the areal density of hard disk drives beyond the conventional density limit, i.e., a near-future target of 1 Tbit/inch^2 and ultimately exceeding 5 Tbit/inch^2. Theoretical studies including a micromagnetic computer simulation in association with an experimental approach are carried out to develop the next generation of high density perpendicular recording devices.

As we have proposed, the magnetic nano-structure of recording media is the most essential parameter to achieve high density perpendicular recording. Bit-patterned medium (Fig 1) is a promising candidate. We have revealed the possibility of an areal density of 5 Tbit/inch^2 in conjunction with heat assisted recording. Disk noise reduction by improving microstructure is in progress.

Research on information storage systems (Fig. 2) is being carried out. High data transfer rate by distributed file system with grouped disk drives was investigated. It was experimentally demonstrated that the data transfer rate of properly designed system was proportional to the number of drives.

[Staff]

Professor: Hiroaki Muraoka, Ph.D. (since 2000)
Associate Professor: Simon J. Greaves, Ph.D. (since 2003)
Secretary: Chie Watanabe

[Profile]

Hiroaki Muraoka joined Tohoku University in 1991. Since then, he has been engaged in research on high-density magnetic recording devices, systems and recording theories, mainly for perpendicular magnetic recording. He received PhD degree in 1981. He is a Fellow of IEEE.
Simon J. Greaves has been at Tohoku University since 2003. He uses micromagnetic simulations at magnetic recording to investigate the potential of future storage devices. He received his Ph.D in 1993 from Salford University, UK.

[Papers]

[1] Akihiro Hara and Hiroaki Muraoka, “Jitter noise reduction by improving grain uniformity in granular media,” J. Appl. Phys., 115, 17B730, May 2014.
[2] Moulay Rachid Elidrissi, Kheong Sann Chan, Simon Greaves, Yasushi Kanai, and Hiroaki Muraoka, “Skew Angle Effects in SMR System with double/triple reader head array,” J. Appl. Phys., 115, 17B53, May 2014

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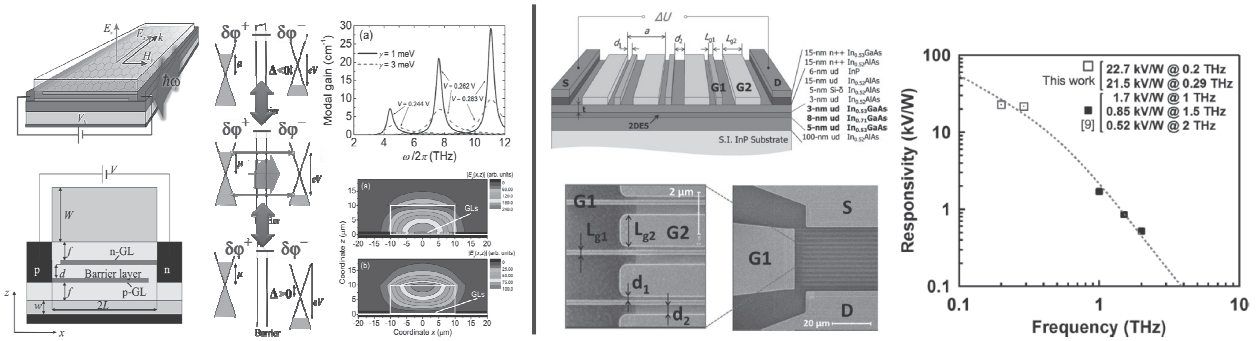
Ultra-broadband Signal Processing

Novel Millimeter-wave and Terahertz Integrated Electron Devices and Systems

Ultra-Broadband Devices and Systems: Taiichi OTSUJI, Professor
Ultrafast Electron Devices: Tetsuya SUEMITSU, Associate Professor
Ultra-Broadband Device Physics: Stephane BOUBANGA TOMBET, Associate Professor

[Research Target and Activities]



Ultrafast photonic, electronic and plasmonic devices using graphene and III-V semiconductors.

(Left: giant terahertz (THz) gain via cooperative resonances of the surface plasmon-polaritons and plasmon-assisted resonant tunneling in optically pumped double-graphene-layer nano-capacitor structure, right: InP-based asymmetric dual-grating-gate (A-DGG) HEMT, fabricated device cross section and SEM images, and record-breaking ultrahigh responsivity in good agreement with theoretical modeling.)

We are developing novel, integrated electron devices and circuit systems operating in the terahertz (THz) region. Recent works and achievements are schematically shown in the above figures.

[Staff]

Professor: Taiichi OTSUJI, Dr. Eng.
Visiting Professor: Victor RYZHII, Ph.D.
Associate Professor: Tetsuya SUEMITSU, Dr. Eng.
Associate Professors: Stephane Albon BOUBANGA TOMBET, Ph.D.
Assistant Professor: Akira SATOU, Dr. Comp. Sci.
Assistant Professor: Susumu TAKABAYASHI, Dr. Eng.
Post-Doctoral Research Fellow: Adrian DOBROIU, Ph.D.
Post-Doctoral Research Fellow: Takayuki WATANABE, Dr. Eng. Secretary: Kayo UENO

[Profile]

Taiichi OTSUJI: received the Dr. Eng. deg. from Tokyo Tech., Japan, in 1994. After working for NTT Labs., Japan, since 1984, he joined Kyutech in 1999, as an Assoc. Prof., being a prof. from 2002. Since 2005, he has been a Prof. at RIEC, Tohoku Univ., Japan. Recipient of the Outstanding Paper Award of the 1997 IEEE GaAs IC Symposium. Distinguished Lecturer, Electron Device Society, IEEE, since 2013. Member of IEEE (Fellow), OSA (Senior), MRS, SPIE, IEICE, and JSAP.

Tetsuya SUEMITSU: received Dr. Eng. from Waseda Univ., Japan, in 2000. Research Scientist, NTT Labs., Japan (1994- 2006); Visiting Scientist, MIT, USA (2002-2003); Assoc. Prof., Tohoku Univ., Japan (2006-). Recipient of the Best Paper Award, IEICE (2003), and the ELEX Best Paper Award, IEICE (2007). Member of IEEE(Senior), APS, JSAP, and PSJ.

Stephane BOUBANGA TOMEBET: received Ph.D. from Montpellier 2 Univ., France, in 2008. JSPS Postdoctoral Research Fellow, Tohoku Univ., Japan (2009-2010); Postdoctoral Researcher, Tohoku Univ., Japan (2011); Physics Consultant, University of Rouen, France (2011); Postdoctoral Researcher, Los Alamos National Lab., USA (2012-2013). Associate Professor, Tohoku Univ., Japan (2013-present).

[Papers]

[1] D. Svintsov, T. Otsuji, V. Mitin, M.S. Shur, and V. Ryzhii, "Negative terahertz conductivity in disordered graphene bilayers with population inversion," Appl. Phys. Lett., Vol. 106, pp. 113501-1-5, March 2015.
[2] K. Kobayashi, S. Hatakeyama, T. Yoshida, Y. Yabe, D. Piedra, T. Palacios, T. Otsuji, and T. Suemitsu, "Improved breakdown voltage and RF characteristics in AlGaN/GaN high electron mobility transistors achieved by slant field plates," Appl. Phys. Express, Vol. 7, pp. 096501-1-4, 2014.
[3] S.A. Boubanga Tombet, Y. Tanimoto , A. Satou , T. Suemitsu , Y. Wang , H. Minamide , H. Ito , D. V. Fateev , V.V. Popov , and T. Otsuji, "Current driven detection of terahertz radiation in dual-grating-gate plasmonic detector," Appl. Phys. Lett., Vol. 104, pp. 262104-1-4, 2014.
[4] Y. Kurita, G. Ducournau, D. Coquillat, A. Satou, K. Kobayashi, S.A. Boubanga-Tombet, Y.M. Meziani, V.V. Popov, W. Knap, T. Suemitsu, T. Otsuji, "Ultrahigh sensitive sub-terahertz detection by InP-based asymmetric dual-grating-gate high-electron-mobility transistors and their broadband characteristics," Appl. Phys. Lett., Vol. 104, pp. 251114-1-4, 2014.

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Aims and Achievements of Human Information Systems Division

To realize advanced information communications systems, it is essential to understand and apply sophisticated information processing mechanisms of human being as well as to establish communications environments in that human can communicate anywhere, anytime without recognizing the communications tools. The aim of this division is to research and develop core and system technologies essential to advanced human friendly information and communications systems through understanding biological information generation mechanisms, human information processing mechanisms focusing on acoustic and visual inputs, and optimizing the communications environments.

To achieve the goal of the Division, four laboratories have been carrying out researches and developments in the following areas: (1) Electomagnetic Bioinformation Engineering, (2) Advanced Acoustic Information Systems, (3) Visual Cognition and Systems, and (4) Ubiquitous Communications Systems.

The goals and achievements in the fiscal year 2013 of each laboratory are described in detail below.

(1) Electomagnetic Bioinformation Engineering

(Aims) To realize future high-definition communications systems with rich and natural sense of presence, this laboratory aims at developing acoustic information processing technologies based on good knowledge of human auditory system as well as multimodal perception relating to hearing.

(Achievements) We obtained highly sensitive strain sensor utilizing the method of inverse-magnetostriction. The sensor shows 10000 times greater sensitivity compare with the conventional strain gage. New method to obtain nano-composite materials by electro-chemical technique was found. This method realizes the high-energy thin film magnet. New mechanism to reduce the iron loss of the magnetic core materials was studied. Collaborating research with steel companies has been started. The study about the magnetic actuator was carried out for tiny pump which can set in blood tube with a manufacturer of medical equipment.

(2)Advanced Acoustic Information Systems

(Aims) To realize future high-definition communications systems with rich and natural sense of presence, this laboratory aims at developing acoustic information processing technologies based on good knowledge of human auditory system as well as multimodal perception relating to hearing.

(Achievement) In FY2013, we deepen the understanding human spatiotemporal perceptual processes of audio-vestibular information. We also studied how the sense of presence and verisimilitude is affected by physical factors involved in multimodal content consisting of auditory, visual and vestibular information. These studies are particularly important to

realize future multi-modal sensory information processing and communication systems. Moreover, we continued to develop advanced acoustic systems. These inlude 3D virtual auditory displays based on our accumulated knowledge of human auditory space perception, sensing and reproduction system based on High-order Ambinonics consisting of over 100 channels, and 252-ch real-time binaural spatial sound sensing system (SENZI). They are keenly required to realize super-definition audio-visual communications in near future.

(3) Visual Cognition and Systems

(Aims) This laboratory aims at understanding the mechanisms of human visual perception in our brain to improve the design of visual information display in the information & communication technologies.

(Achievements)

Firstly, we investigated coordinated movements of eyes and head in vision for action. We found multiple saccades during one continuous head movement, and the contribution of head movement increased with the number of saccades. This relationship suggests eye-head coordination over several saccade-fixation sequences suggests the role of eye-head coordination in visual cognitive processing. Secondly, we investigated effect of material perception on the mode of color appearance. The change in mode of color appearance between surface and light source was tested in relation to the material perception from the display media. The subjects showed concrete perception of surface when fabric material was perceived with high convincingness. The present result demonstrated that the discrepancy between display media for digital publishing might be solved by displaying compelling perception of material surface property.

Electromagnetic Bioinformation Engineering

Communication with human body

Electromagnetic Bioinformation Engineering, Kazushi Ishiyama, Professor
Electromagnetic Biomaterial Engineering, Shuichiro Hashi, Associate Professor

[Research Target and Activities]

We studied the mechanism of obtaining the magnetic anisotropy of the magnetic thin films for the sensitive magnetic sensors. We obtained a non-metal probe for high frequency magnetic field, and confirmed the probe can measure the high frequency magnetic field with its phase information. In addition, 3D position detecting system using magnetic markers was studied to improve its position accuracy. The study about the magnetic actuator driven by the external magnetic field was carried out for biomimetic robots using the rotational magnetic field, and small wireless pumps were obtained and clarified for their application for an artificial heart-support pump.

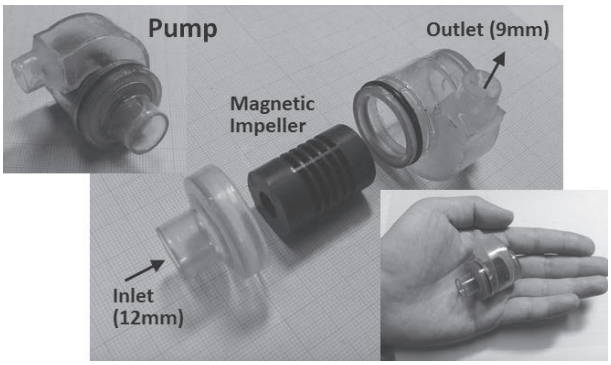

Fig. 1 Prototype of wireless artificial heart assist blood pump[1]

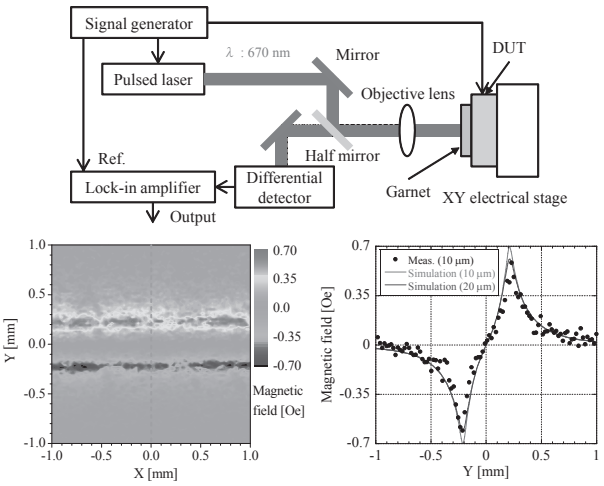

Fig. 2 High frequency magnetic field imaging system using magneto-optical crystal probe

[Staff]

Professor: Kazushi Ishiyama, Dr.
Associate Professor: Shuichiro Hashi, Dr.
Assistant Professor: Sung Hoon Kim, Dr.

[Profile]

Kazushi Ishiyama received his MS and PhD degrees in Electrical Engineering from Tohoku University in 1986 and 1993, respectively. His research interests are in the area of magnetics and magnetic applications.

Shuichiro Hashi received the DE degree in Electrical Engineering from Tohoku University in 1998. His research interests are in the area of magnetic measurement and magnetic materials.

[Papers]

[1] S. H. Kim, K. Ishiyama, "Hybrid Speed Control of a DC Motor for Magnetic Wireless Manipulation Based on Low-Power Consumption: Application to a Magnetic Wireless Blood Pump," IEEE Transactions on Magnetics, Vol. 50, No. 4, p. 5000307, April (2014).
[2] J. Shin, Y. Miwa, K. H. Kim, S. Hashi, K. Ishiyama, "Observation of the magnetic properties according to changes in the shape of thin-film giant magnetoimpedance sensor," IEEE Transactions on Magnetics, Vol. 50, No. 11, p. 4005603, November (2014).
[3] Y. Miwa, J. Shin, Y. Hayashi, S. Hashi, K. Ishiyama, "Basic study of fabricating high sensitive strain sensor using magnetostrictive thin film on Si wafer," IEEE Transactions on Magnetics, Vol. 51, No. 1, p. 2000604, January (2015).

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Advanced Acoustic Information Systems

Development of next generation communication systems

Advanced Acoustic Information Systems: Yôiti Suzuki, Professor
Auditory and Multisensory Information Systems: Shuichi Sakamoto, Associate Professor

[Research Target and Activities]

The main interest of this laboratory is the study of information processing by the human auditory system. At the same time, we aim to realize a 'comfortable' sound environment by exploiting digital signal processing techniques. One example is the development of three-dimensional auditory displays, which present sound images by simulating the transfer functions for the sound paths from the sound sources to the listeners' external ears. Another example is the proposal of 3D sound field information sensing systems. These systems are expected to convey a high-quality virtual sound space, which is keenly sought for multimedia communications, cyberspace systems and virtual reality systems. Moreover, in 2014, we put a lot of effort to develop systems to acquire 3D sound-space information capable of saving, transmitting, and reproducing accurate sound-space information at a distant place. In regards to three-dimensional sound space information recording using microphone arrays, we proposed the use of spherical and cylindrical arrays with numerous microphones on their surfaces. From a psychoacoustical point of view, we also investigated the effect of self-motion, including head rotation, on the auditory space perception.

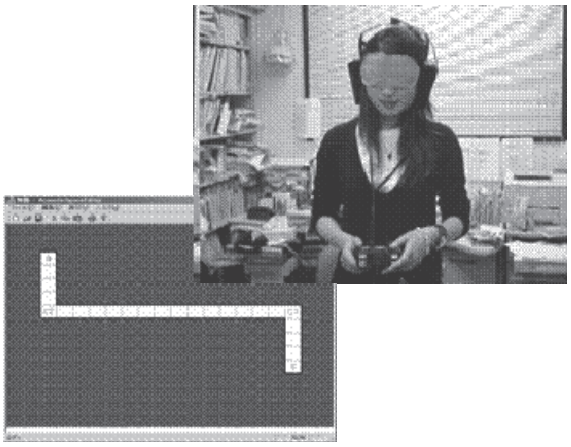

Fig. 1 Application for the training of spatial cognition using a high-definition virtual auditory display

[Staff]

Professor: Yôiti Suzuki, Dr., Associate Professor: Shuichi Sakamoto, Dr.,
Assistant Professor: Tomoko Ohtani, Dr., Jorge Treviño, Dr., Research Fellow: Zheng Lie Cui, Dr.
Technical Staff: Fumitaka Saito

[Profile]

Yôiti Suzuki graduated from Tohoku University in 1976 and received his Ph. D. degree in electrical and communication engineering in 1981. His research interests include psychoacoustics and digital signal processing of acoustic signals. He served as president of the Acoustical Society of Japan from '05 to '07. He is a fellow of the Acoustical Society of America.
Shuichi Sakamoto graduated from Tohoku University in 1997 and received his Ph. D. degree in electrical and communication engineering in 2004. His research interests include human auditory and multisensory information processing and development of advanced multimodal information systems.

[Papers]

[1] W. Teramoto, Z-L. Cui, S. Sakamoto and J. Gyoba, "Distortion of auditory space during visually induced self-motion in depth," Frontiers in Psychology, 5, 848 (2014).
[2] S. Sakamoto, S. Hongo and Y. Suzuki, "3D sound-space sensing method based on numerous symmetrically arranged microphones," IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences, E97-A(9), 1893-1901 (2014).
[3] J. Trevino, S. Koyama, S. Sakamoto and Y. Suzuki, "Mixed-order Ambisonics encoding of cylindrical microphone array signals," Acoustical Science and Technology, 35(3), 174-177 (2014).

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Visual Cognition and Systems Laboratory

Understanding human visual system for the better communication with visual information

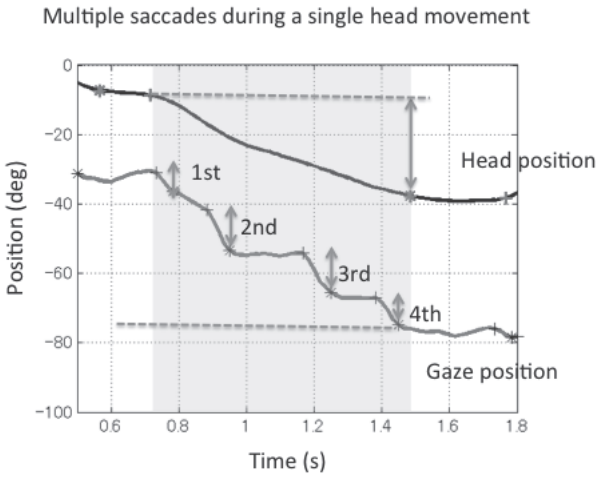
Visual Cognition and Systems Satoshi SHIOIRI, Professor

Cognitive Brain Functions Ichiro KURIKI, Associate Professor

[Research Target and Activities]

1. Eye-head coordination for visual cognitive processing

We investigated coordinated movements of eyes and head ("eye-head coordination") in vision for action. We found multiple saccades during one continuous head movement, and the contribution of head movement increased with the number of saccades. This relationship suggests eye-head coordination over several saccade-fixation sequences suggests the role of eye-head coordination in visual cognitive processing.



2. Effect of material perception on the mode of color appearance.

The rays that appear brown and gray from object surfaces appear dark orange and dark white, respectively, when they appear to be emitted from light sources. This change in mode of color appearance was tested in relation to the material perception from the display media. The subjects showed concrete perception of surface when fabric material was perceived with high convincingness. The present result demonstrated that the discrepancy between display media for digital publishing might be solved by displaying compelling perception of material surface property.

[Staff]

Professor: Satoshi SHIOIRI
Associate Professor: Ichiro KURIKI
Associate Professor: Kazumichi MATSUMIYA

[Profile]

Satoshi SHIOIRI: Received Dr. Eng from Tokyo Institute of Technology in 1986. He was a postdoctoral researcher at University of Montreal (until May, 1989) and at Advanced Telecommunications Research Institute (until April, 1990). He worked at Chiba University, as an assistant professor, an associate professor, and a professor until February, 2005. In March 2005, he moved to Research Institute of Electrical Communication, Tohoku University as a professor.

Ichiro KURIKI: Received Ph.D. degree from Tokyo Institute of Technology in 1996. He worked at Tokyo Institute of Technology (until September 1999), at the University of Tokyo (until March, 2001) as a research associate, and for NTT-CS Labs. until December, 2005. He joined the Research Institute of Electrical Communication, Tohoku University as an Associate Professor in January, 2006.

[Papers]

[1] Fang, Y., Nakashima, R., Matsumiya, K., Kuriki, I. & Shioiri, S. Eye-head coordination for visual cognitive processing. *PloS one* **10**, e0121035 (2015).

[2] Fang Y, Emoto M, Nakashima R, Matsumiya K, Kuriki I, Shioiri S: Eye-position distribution depending on head orientation when observing movies on ultrahigh-definition television. ITE Transactions on Media Technology and Applications 3(2), 149-154, 2015

[3] Horiuchi, K., Kuriki, I., Tokunaga, R., Matsumiya, K. & Shioiri, S. Chromatic induction from surrounding stimuli under perceptual suppression. *Visual neuroscience* **31**, 387-400 (2014).

[4] Kuriki, I. (2015). Lightness dependence of achromatic point loci in color-appearance coordinates. *Frontiers in Psychology*, **6**:67, 2015. doi: 10.3389/fpsyg.2015.00067

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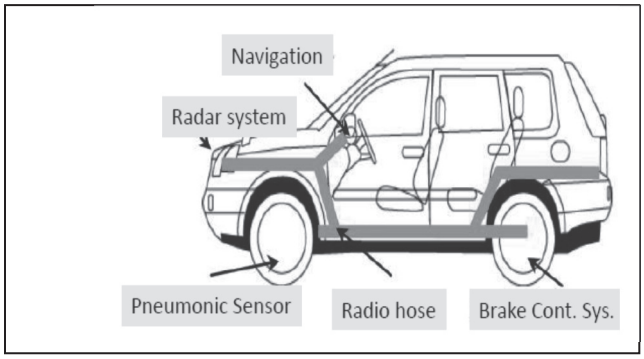
Ubiquitous Communications System

Realization of Wireless Harness System and Wide Area Sensor Networks



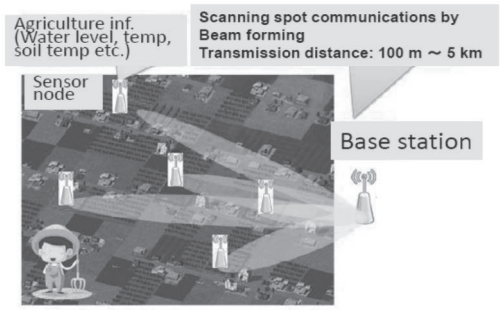


Fig. 2 Image of Wide Area Wireless Sensor Networks

Ubiquitous Communications System: Shuzo Kato, Professor

[Research Target and Activities] The goal of ubiquitous communications is to provide communications environments in which everybody can communicate with anybody, anywhere and anytime without paying attention on the communications tools much. The laboratory has been working on core technology R&D on ubiquitous communications.

[FY2014 Major Results]

1) **Hi reliable Wireless Harness Systems**

Successfully reduced wired harness weight to 1/10, increased the transmission speed by 10,000 times and higher reliability than wired harness. Various materials for the small diameter radio hoses have been validated and has progressed to the practical implementation level very well.

2) **Wide Area Sensor Networks**

Through the propagation tests in Rural, City areas, the 5 km transmission capability with 90 % probability has been validated that is good enough for practical applications. Also fast chip synchronization and low C/N demodulation schemes have been developed to clarify the transmission and anti-interference performances(Fig.2). They have effectively proved the practical implementation of 900 MHz wide area sensor networks in Japan.

[Staff]

Prof.: Shuzo Kato, Ph.D, Technical staff: Tuncer Baykas(~8/E/ 2014), Technical assistant: Naomi Aizawa(~ 7/E/2014)

[Profile]

A Manager, Researcher and Engineer having a successful broad range of experiences from R&D, Manufacturing, Quality management, Product planning, Marketing, Sales, HRs in Japan and USA. Recently working on millimeter wave communications systems and wide area sensor networks. Graduated from Faculty of Engineering, Tohoku University with Ph. D in 1977, Published over 300 technical papers and held over 100 patents, Fellow of the IEEE and IEICE Japan.

[FY2014 Major Papers]

1. T. Baykas and S. Kato. “On the Spectrum Efficiency of Mesh and Star Topology Wider Area Wireless Sensor Networks", Proc. of PIMRC2014, 2014, Washington DC, USA.
2. Yosuke Sato、 Shuzo Kato、“Small and Low Side Lobe Beam-forming Antenna Composed of Narrow Spaced Patch Antennas for Wireless Sensor Networks”, SENSORCOMM 2014 November, 2014 Lisbon Portugal
3. Yasutaka Tada and Shuzo Kato,”High Deployability of IEEE 802.15.4k DSSS Systems in Interference Dominated Bands” SENSORCOMM 2014 November, 2014 Lisbon Portugal

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Research Targets and Activities of Systems & Software Division

The goal of System & Software Division is to realize Ubiquitous environment. In an ideal ubiquitous environment, everyone can communicate with anybody, anywhere, with any kind of information, at any time, freely and in real time. Our division has the following five research fields related to such high-level system, software and content by integrating computer and communication:

— Software Construction: Reliable and high-level software.
— Computing Information Theory: Fundamental theory of new software.
— Communication Network: Symbiotic computing.
— Information Content: Technologies for interactive content.
— Structure of Information Society (Visitor Section).

An overview of research results from Apr. 2014 to Mar. 2015 of these fields except the visitor section is described in this section.

(1) Software Construction

We have been researching on theoretical foundations for flexible and reliable programming languages, and have been developing SML#, a new programming language in the ML family embodying our research results. The major results of the 2014 academic year include the following. (1) We developed an approach for constructing a formal semantics of Ruby, a practical programming language, by decomposing its entire semantics into independent calculi and combining them systematically. (2) Development of the SML# compiler includes the following: (i) We added the latest 64-bit platform support to SML# compiler. (ii) We developed a feature that supports efficient code reading by extracting a variable reference relationship from SML# programs.

(2) Computing Information Theory

Rewriting systems are mathematicalformalisms which can offer both flexible computing and effective reasoning with equations. Our research focuses on theoreticalfeatures of rewriting systems and applications to automated theorem proving, algebraic specifications, and functional and logic programming languages. The main results of this year are as follows. (i) We proposed a new formalization of orthogonal nominal rewriting systems, which is a framework of higher-order rewriting systems with variable binding. The new formalization offers a confluence condition effectively applicable to many standard nominal rewriting systems. (ii) We continued to develop an automated confluence prover ACP for term rewriting systems based on various proof techniques. In the 3rd confluence competition (CoCo 2014), ACP has won first place.

(3) Communication Network

In a research project on applications of Active Information Resources, a management method of ICT units allocated dynamically, and a cooperation method of heterogeneous contents for user-oriented information navigation system are developed. A study on applications of regional network in usual/unusual situation is launced and a conceptual design on a personalization method of regional servieces based on mesh networks is started. On the other hand, in a research project on multiagent-based sensor infrastructure, a method of agentification of an IoT device is developed and verified its usefulness by the development of prototype systems. Furthermore, in the studies on evolutional agent systems, a measure of observing system's behavioral situation for system monitoring is proposed and validated its effectiveness. Moreover, a design of dynamic deployment method of agent platforms over the distributed environment is started.

(4) Information Content

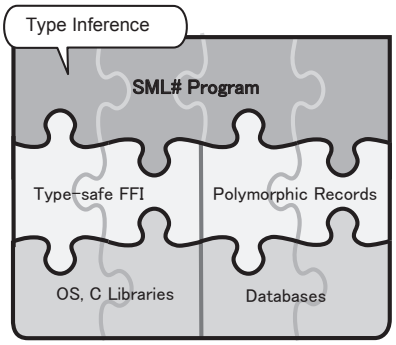
We are conducting comprehensive research on a variety of technologies rerated to interactive content which creates new value through interactions with humans. This year we firstly developed a novel touch scroll interface that achieves continuous scroll across on and off screen surfaces. Secondly, we developed MovemenTable, which is an exploration of moving interactive tabletops. It can physically move, gather together or depart according to people's dynamically varying interaction tasks and collaborative needs. Thirdly, the joint research project intended to commercialization with industry in terms of D-FLIP, which is our algorithm to interactively, flexibly, and dynamically display a set of digital photographs, was on track this year and was determined to be commercialized.

Softwere Construction Laboratory

Foundations for Developing High-level and Reliable Programming Languages

Software Construction Atsushi Ohori, Professor

[Research Target and Activities]



SML#: a high-level and reliable language

Today's software systems are becoming more and more complicated due to the need of integrating various computation resources available in the Internet. A key to control the complexity and to enhance the reliability of such a system is to develop a high-level programming language that can directly represent various resources and automatically detect potential inconsistencies among the components in a system. Based on this general observation, our research aims at establishing both firm theoretical basis and implementation method for flexible yet reliable programming languages for advanced applications. Research topics on theoretical foundations include: logical foundations for compilation, verification of low-level code, and type-directed compilation for polymorphic languages. We are also developing a new practical ML-style programming language, SML#, which embodies some of our recent results such as record polymorphism, rank-1 polymorphism, and high-degree of inter-operability with existing languages and databases.

The major results of the 2014 academic year include the following. (1) Developments in theoretical foundations: we presented a formal operational semantics of Ruby by decomposing Ruby into a set of well-structured components, each of which is a straightforward specification of individual language feature. (2) Development of the SML# compiler: We extended the SML# compiler to the latest 64-bit platforms by adding 64-bit support to the compiler frontend, the SML# runtime and the basis library. We also developed a tool that assists code-reading by using name dependencies calculated by the compiler.

[Staff]

Professor : Atsushi Ohori, Dr.
Assistant Professor : Katsuhiro Ueno, Dr.

[Profile]

Atsushi Ohori Professor Atsushi Ohori was born in 1957. He received his BA degree in Philosophy from University of Tokyo, 1981; received his MSE degree in Computer and Information Science from University of Pennsylvania, 1986; and received his Ph.D. degree in Computer and Information Science from University of Pennsylvania, 1989. He worked for Oki Electric Industry as a programmer, a researcher and a senior researcher from 1981 until 1993. From 1989 until 1990, he spent one year in University of Glasgow as a postdoctoral research fellow funded by Royal Society Research Fellowship. In 1993, he joined Research Institute for Mathematical Sciences, Kyoto University as an Associate Professor. In 2000, he joined Japan Advanced Institute of Science and Technology as a Professor. In 2005, he moved to RIEC, Tohoku University as a Professor.

[Papers]

[1] Atsushi Ohori, Katsuhiro Ueno, Kazunori Hoshi, Shinji Nozaki, Takashi Sato, Tasuku Makabe, Yuki Ito. SML# in Industry: A Practical ERP System Development. In Proceedings of The 19th ACM SIGPLAN International Conference on Functional Programming, 2014.
[2] Katsuhiro Ueno, Yutaka Fukasawa, Akimasa Morihata, Atsushi Ohori. The Essence of Ruby. In: Programming Languages and Systems, 12th Asian Symposium, APLAS 2014, Lecture Notes in Computer Science, Vol. 8858, pp. 78-98, 2014.

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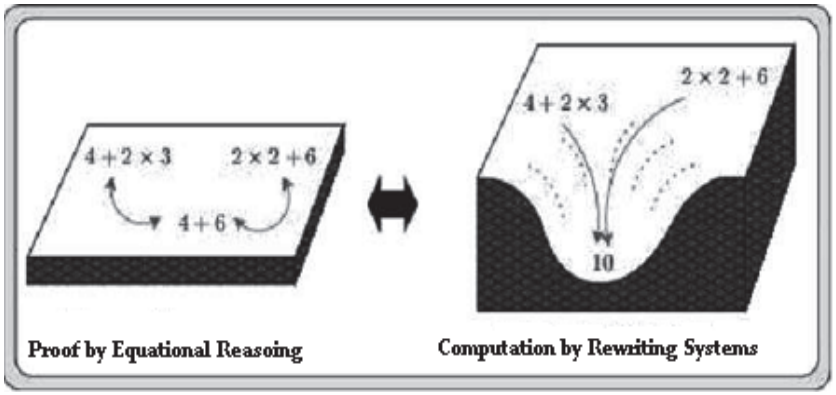
Computing Information Theory

Towards a New Software Paradigm Arising from Computation and Proof

Computing Information Theory **Yoshihito TOYAMA, Professor**
Computing logical system **Takahito AOTO, Associate Professor**

[Research Target and Activities]

We are working on the development of a new software paradigm that arises from computation and proof. For this, we focus on a rewriting formalism which offers both flexible and effective reasoning with equations. In the rewriting formalism, proofs by equational reasoning and computations by rewriting systems can be combined in a unified framework (see the figure above). We aim at applying our new paradigm to the development of formal techniques for construction and verification of reliable software. We are currently working on rewriting theories for termination, confluence, program transformation, and program verification. Recent research activities include higher-order rewriting systems, automated inductive theorem proving, combination of functional-logic languages and automated theorem proving systems.



[Staff]

Professor : Toyama, Yoshihito Dr
Associate Professor : Aoto, Takahito Dr
Assistant Professor : Kikuchi, Kentaro Dr

[Profile]

Professor TOYAMA Yoshihito Toyama was born in 1952. He received his B.E. from Niigata University in 1975, and his M.E. and D.E. from Tohoku University in 1977 and 1990. He worked as a Research Scientist at NTT Laboratories from 1977 to 1993, and as a Professor at the Japan Advanced Institute of Science and Technology (JAIST) from 1993 to 2000. Since April 2000, he has been a professor at the Research Institute of Electrical Communication (RIEC) of Tohoku University. His research interests includes term rewriting systems, program theory, and automated theorem proving.

Associate Professor Takahito AOTO Takahito Aoto was born in 1969. He received his M.S. and Ph.D. from Japan Advanced Institute for Science and Technology (JAIST). He was at JAIST from 1997 to 1998 as an associate, at Gunma University from 1998 to 2002 as an assistant professor, and at Tohoku University from 2003 to 2004 as a lecturer. He has been in Tohoku University from 2004 as an associate professor. His current research interests include rewriting systems, automated theorem proving, and foundation of software.

[Papers]

[1]Kentaro Kikuchi , Takafumi Sakurai , A Translation of Intersection and Union Types for the $\lambda\mu$-Calculus, In Proceedings of the 12th Asian Symposium on Programming Languages and Systems, LNCS 8858, pp. 120–139, 2014.

[2]Takahito Aoto, Yoshihito Toyama , Kazumasa Uchida, Proving confluence of term rewriting systems via persistency and decreasing diagrams, Proceedings of Joint 25th International Conference on Rewriting Techniques and Applications and 12th International Conference on Typed Lambda Calculi and Applications (RTA-TLCA 2014), Vienna, Austria, LNCS 8560, pp. 46–60, 2014.

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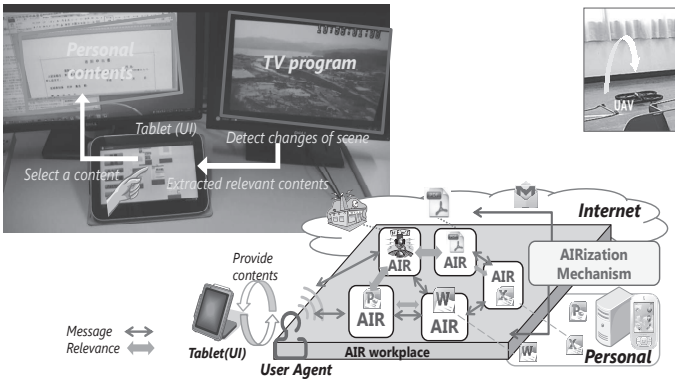
Communication Network Systems

Support for Cooperation and Communication between Human and Systems

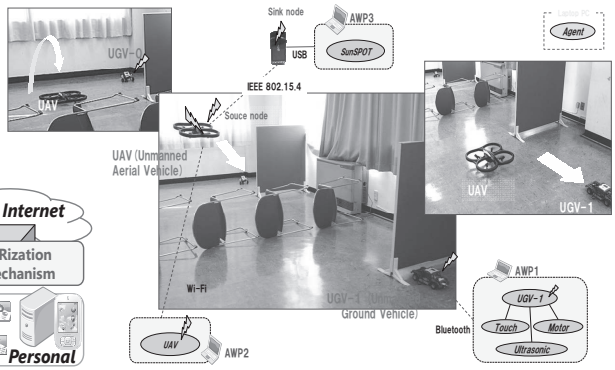
Intelligent Communication Tetsuo Kinoshita, Professor
Intelligent Network Gen Kitagata, Associate Professor

[Research Target and Activities]

In this year, the following studies have been done. (a) Active Information Resources: A management method of ICT units allocated dynamically and a cooperation method of heterogeneous contents for user-oriented information navigation system are developed. (b) Multiagent-based sensor infrastructure: A method of agentification of an IoT (Internet of Things) device and a cooperation mechanism are developed and verified its usefulness by the development of prototype systems.



User-Oriented Information Delivery System Using Active Information Resources



Multiagent-based Cooperation of IoT Devices

[Staff]

Professor : Tetsuo Kinoshita, Dr.
Associate Professor : Gen Kitagata, Dr.
Assistant Professor : Hideyuki Takahashi, Dr.
Assistant Professor : Kazuto Sasai, Dr.

[Profile]

Tetsuo Kinoshita received his B.E. degree in electronic engineering from Ibaraki University, Japan, in 1977, and M.E. and Dr.Eng. degrees in information engineering from Tohoku University, Japan, in 1979 and 1993, respectively. He received the IPSJ Research Award, the IPSJ Best Paper Award and the IEICE Achievement Award in 1989, 1997 and 2001. Dr. Kinoshita is a member of IEEE (SM), ACM, AAAI, IEICE (Fellow), IPSJ (Fellow) and JSAI.

Gen Kitagata is an associate professor of the Research Institute of Electrical Communication of Tohoku University, Japan. He received a doctoral degree from the Graduate School of Information Sciences, Tohoku University in 2002. His research interests include agent-based computing, network middleware design, and symbiotic computing. He is a member of IEICE and IPSJ.

[Papers]

[1] W. Wei, A. Takahashi, T. Kinoshita, "Design and Evaluation of Energyconsumption-aware Evolutional Agent System for Portable Devices," Journal of Information Processing, No.22, Vol.4, pp.660–668, Oct. 2014.
[2] K. Sasai, "A Review of Morphological Computation from a Perspective of Hetearchy," In Helmut Hauser, Rudolf M. Füchslin, Rolf Pfeifer (eds.), Opinions and Outlooks on Morphological Computation, ISBN 978-3-033-04515-6, 2014.
[3] T. Kinoshita, H. Takahashi, K. Sasai, G. Kitagata, "User-Oriented Information Delivery System Using Active Information Resources," Advanced and Applied Convergence Letters (AACL 03), pp.240-243, Nov. 2014.

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Information Content

Technologies for Interactive Content

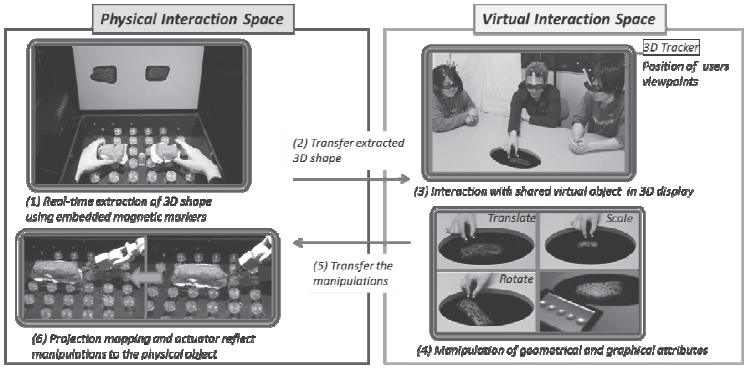
Interactive Content Design Yoshifumi KITAMURA, Professor

[Research Target and Activities]

Good media content has the power to enrich our lives. The effectiveness of content delivery is becoming more and more important in a wide variety of fields, such as industry, education, culture, entertainment, and so on. Expectations of its use in the general public are also increasing. We focus on non-traditional contents other than movies, music and games, conducting comprehensive research on a variety of interactive content which creates new value through interactions with humans. This year we mainly conduct research projects about evaluation of dynamic and a flexible interactive display method, a magnetic motion tracking system for dexterous 3D interactions, and a 3D cooperative interaction environment connecting physical and virtual worlds, and so on.

[Staff]

Professor: Yoshifumi Kitamura, Dr.
Assistant Professor: Kazuki Takashima, Dr.



Coupled-Clay: Physical-Virtual 3D Collaborative Interaction Environment

[Profile]

Yoshifumi KITAMURA received B.Sc., M.Sc. and PhD. degrees in Engineering from Osaka University in 1985, 1987 and 1996, respectively. From 1987 to 1992, he was at the Information Systems Research Center of Canon Inc. From 1992 to 1996, he was a researcher at the ATR Communication Systems Research Laboratories. From 1997 to 2002, he was an Associate Professor at the Graduate School of Engineering and Graduate School of Information Science and Technology, Osaka University. Since April 2010, he has been a Professor at the Research Institute of Electrical Communication, Tohoku University. He is a fellow of the Virtual Reality Society of Japan.

[Papers]

[1] Kasim Ozacar, Takuma Hagiwara, Jiawei Huang, Kazuki Takashima, Yoshifumi Kitamura, Coupled-Clay: Physical-Virtual 3D Collaborative Interaction Environment, Proceedings of IEEE Virtual Reality 2015, March 2015.

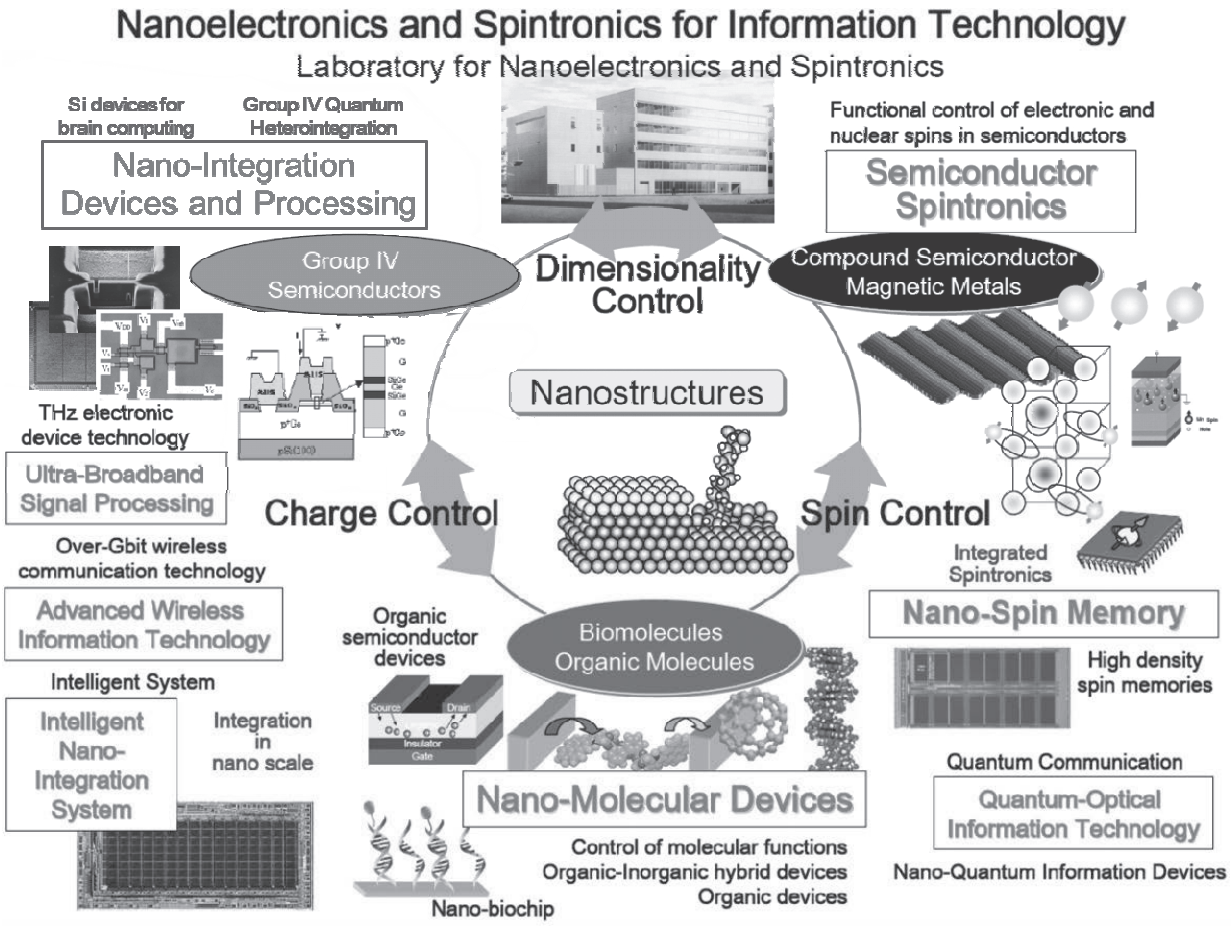
[2] Jiawei Huang, Kazuki Takashima, Shuichiro Hashi, Yoshifumi Kitamura, IM3D: Magnetic Motion Tracking System for Dexterous 3D Interactions, SIGGRAPH 2014 Emerging Technologies, August 2014.

[3] Chi Thanh Vi, Kazuki Takashima, Hitomi Yokoyama, Gengdai Liu, Yuichi Itoh, Sriram Subramanian, Yoshifumi Kitamura, A dynamic flexible and interactive display method of digital photographs, Entertainment Computing, Volume 5, Issue 4, pp. 451-462, November 2014.

Laboratory for Nanoelectronics and Spintronics

The Laboratory for Nanoelectronics and Spintronics of the Research Institute of Electrical Communication was established on April of 2004. Its purpose is to develop and establish the science and technology of nanoelectronics and spintronics for information technology. Utilizing the facilities installed in the Nanoelectronics-and-Spintronics building and under collaboration between the RIEC and electro-related laboratories of the Graduate Schools of Engineering, Information Sciences, Biomedical Engineering, Tohoku University, R&D of nanotechnologies of materials and devices in Nanoelectronics and Spintronics will be continued extensively. Furthermore, nation-wide and world-wide collaboration research projects will be conducted to build a systematic database in the electrical communication research area.

The Laboratory for Nanoelectronics and Spintronics mainly consists of research groups which promote following sections: Nano-Integration Devices and Processing, Semiconductor Spintronics and Nano-Molecular Devices; together with the groups of Intelligent Nano-Integration System, Quantum-Optical Information Technology, and Ultra-Broadband Signal Processing. These groups cooperatively carry out the research aimed at establishing a world-wide COE in the research area of nanoelectronics and spintronics.



Highlights of Research Activities in 2014

Nano Integration

● Nano-Integration Devices and Processing (S. Sato and M. Sakuraba)

(1) Toward the integration of quantum nano-devices, we have studied on STM lithography using hydrogen resist for manipulation of a single atom. We confirmed desorption of hydrogen atoms on a hydrogen-terminated Si surface, which was obtained by a treatment in a NH_4F aqueous solution with low dissolved oxygen concentration, by injecting electrons from an STM tip. As a result, we have found that desorption of hydrogen atoms occurs for a bias voltage larger than 3.1V, and also that the area of desorption is proportional to the injection current.

(2) Epitaxial growth of strained SiGe alloy on Si(100) using low-energy ECR plasma CVD without substrate heating has been studied. It is found that increasing tendency of reaction rates for SiH_4 and GeH_4 with increase of Ge fraction is dependent on partial pressure region. Moreover, it is found that epitaxial growth of a Si / strained SiGe alloy / Si heterostructure with superior flatness and abruptness of surface and interface can be realized in the smaller partial pressure region.

(3) As a first step to develop a spatial perception system by using motion-stereo vision, we have designed an LSI in which local-motion is detected. We have confirmed by RTL (Register Transfer Level) simulation that the frame rate of 70 fps in 100 MHz operation can be achieved combined with a 3-stage pipeline.

● Intelligent Nano-Integration System (K. Nakajima)

(1) We proposed an inverse function delay-less (IDL) model for high speed numerical calculation of artificial neural networks, and we combined the model with a DS-Net and succeeded to apply to some problems in TSP-LIB with up to 51 cities. (2) We applied an IDL model to back propagation (BP) learning with higher success rate and succeeded to analyze the dynamical operation to explain the solving of local minimum problems in the BP learning. (3) We fabricated a superconducting Schmitt trigger inverter and demonstrated successfully a relaxation oscillator using the inverter.

Semiconductor Spintronics and Information Technology

● Semiconductor Spintronics(H. Ohno)

Our research activities focus on realizing low-power functional spintronic devices. The outcomes in the last fiscal year are following. (1) Preparation of (Ga,Mn)As with large magnetization by codoping with Li. (2) Demonstration of different relationship between electrical conductivity and Hall conductivities of (Ga,Mn)Sb from that of (Ga,Mn)As. (3) Demonstration of a scheme for magnetization switching in magnetic tunnel junctions (MTJs) with two successive voltage pulses to utilize both spin-transfer torque and electric field effect. (4) Clarification of the junction size dependence of magnetic properties of a CoFeB free layer in CoFeB-MgO based MTJs from 35 nm to 100 nm in diameter by homodyne-detected ferromagnetic resonance. (5) Clarification of junction size

dependence of thermal stability factor and intrinsic critical current in perpendicular-anisotropy MTJs with double CoFeB-MgO interface down to world's smallest junction diameter of 11 nm. (6) Demonstration of enhanced thermal stability and writing properties of domain wall-motion device with decreasing the dimensions down to 20 nm.

1. Research activities in "Research and Development of Spintronics Material and Device Science and Technology for a Disaster-Resistant Safe and Secure Society" program under Research and Development for Next-Generation Information Technology of MEXT. (1) Demonstration of controlling B composition, and thus magnetic properties of CoFeB film in MgO-CoFeB-Ta stack by changing CoFeB and Ta thicknesses as well as annealing condition. (2) Clarification of origin of magnetic anisotropy in Ta/CoFeB/MgO junction by x-ray magnetic circular dichroism. (3) Determination of electric-field modulation ratio of magnetic anisotropy in CoFeB-MgO MTJ by homodyne-detected ferromagnetic resonance and (4) X-band ferromagnetic resonance.
2. Research activities in "Achieving ultimate Green IT Devices with long usage times without charging" program under Impulsing Paradigm Change through Disruptive Technologies Program of CAO. (1) Determination of university classes of current- and external magnetic field-induced domain wall motion in CoFeB/MgO wire. (2) Demonstration of perpendicular-anisotropy MTJs with double CoFeB-MgO interfaces having capability to withstand annealing at 400ºC required for standard back-end-of-line process.

● Ultra-Broadband Signal Processing (T. Otsuji, T. Suemitsu, and S. Boubanga-Tombet)

1. Ultra-Broadband Devices and Systems

   We are developing novel, integrated electron devices and circuit systems operating in the millimeter-wave and terahertz regions. III-V- and graphene-based active plasmonic heterostructures for creating new types of terahertz lasers and ultrafast transistors are major concerns. By making full use of these world-leading device/circuit technologies, we are exploring future ultra-broadband wireless communication systems as well as spectroscopic/imaging systems for safety and security.
2. Ultrafast Electron Devices

   We are focusing on two important material systems for high-speed and high-frequency devices: the indium gallium arsenide (InGaAs) for ultimately high-frequency operation including sub-millimeter-wave regime, the gallium nitride (GaN) for high-power millimeter-wave applications. Our activities include the design, process, and characterization of these devices and their integrated circuits.
3. Ultra-Broadband Device Physics

   We theoretically and experimentally investigate the physics of plasmonics in III-V semiconductor- and graphene-based heterostructure material systems and their device applications. Our main goal is to develop new and original plasmonic integrated devices operating in the millimeter-wave and terahertz regions for the next generation of imaging,

spectroscopy, and ultra-broadband communication systems.

● **Quantum-Optical Information Technology (K. Edamatsu and Y. Mitsumori)**

1. We are experimentally investigating error-disturbance uncertainty relations in quantum measurements. We have demonstrated in photon polarization measurement that the Heisenberg error-disturbance uncertainty relation (EDR) is violated while the EDRs proposed by Ozawa and Branciard hold. We also have examined the condition in which Heisenberg relation is attained.

2. We have investigated the excitonic Rabi oscillations in semiconductor quantum dots using a single dot spectroscopy for the development of the optical coherent manipulation of the electric states in the quantum dots. We have observed the interesting behavior of the Rabi oscillations arising from the longitudinal electric field effect of the excitonic polarization in a quantum dot.

Nano-Molecular Devices

● **Nano-Molecular Devices (M. Niwano)**

1. Fabrication of polymer/TiO_2-nanotube-based hybrid structures: The incomplete infiltration and non-uniform coating of polymer material in inorganic nanostructures have hindered the applications of hybrid nanostructure. In this work, a novel solvent-vapor-assisted coating (SVAC) method is proposed for uniform coating of polymers in inorganic nanostructure. Hybrid solar cells, made by filling the tube-in-tube structure with hole transporting material, produced drastically improved short circuit current and serial resistance. (Mater. Res. Express)
2. Improvement of Electrical Characteristic of P3HT Organic Electrochemical Transistors (OECTs) with Ionic Liquid: We fabricated P3HT OECTs with an ionic liquid by varying conditions of annealing, and investigated effects of annealing temperature and process on the P3HT crystallinity and the characteristics of P3HT OECTs. We found that increasing a crystallinity of an organic active layer by slow cooling in annealing process is crucial to improving electrical characteristic of OECTs. (ECS 226th meeting)
3. The onset and closure of critical period plasticity regulated by feedforward inhibition: Synaptic circuits are highly sensitive to sensory experience during a critical period in early development. The maturation of GABA inhibition in the visual cortex is suggested to be required for both the onset and closure of the critical period for ocular dominance (OD) plasticity, although the underlying mechanism is unclear. This study examines a model of a visual cortical cell to investigate the mechanism by which inhibitory pathway regulates OD plasticity, through the competition between the groups of correlated inputs from two eyes. (Neurocomputing **143**, 261 (2014))

Nano-Integration Devices and Processing

Nano-integration beyond the existing technology

Nano-Integration Devices — Shigeo Sato, Professor
Group IV Quantum Heterointegration — Masao Sakuraba, Associate Professor

[Research Target and Activities]

In addition to the conventional demands such as faster operation and larger throughput, low power operation for low-carbon emission and robust operation not damaged even in a disaster are required for the development of the next generation information technology. To meet these demands, studies on high functional and high performance Si-based semiconductor devices realized by 3-D nano-processing and large scale integration of such devices are important research subjects. We study the subjects such as new transistors and memories using new materials, new devices based on new principles like quantum effects, and required 3-D processing. Moreover, we develop advanced technologies related to 3-D nano-integration, dependable mixed signal LSI, and non von Neumann architecture.

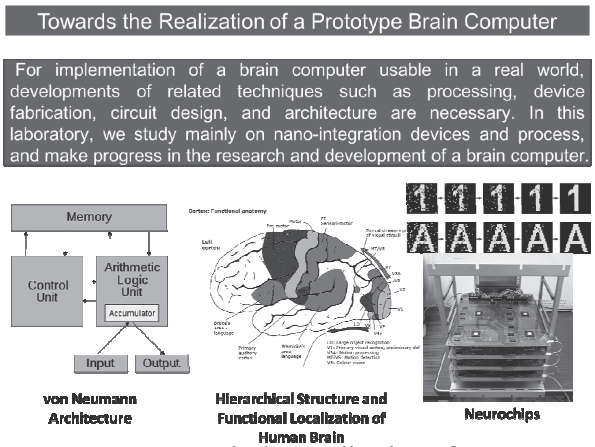
In this year, following experimental results have been obtained: 1) STM lithography using hydrogen resist for manipulation of a single atom has been studied. It is confirmed that desorption of hydrogen atoms on a hydrogen-terminated Si surface by electron bombardment, and that the area of desorption is proportional to the injection current. (2) Epitaxial growth of strained SiGe alloy on Si(100) using low-energy ECR plasma CVD without substrate heating has been studied. It is found that epitaxial growth of a Si / strained SiGe alloy / Si heterostructure with superior flatness and abruptness of surface and interface can be realized in the smaller partial pressure region.

[Staff]

Professor : Shigeo Sato, Dr.
Associate Professor : Masao Sakuraba, Dr.
Assistant Professor : Nobuyuki Sato, Dr.
Assistant Professor: Hisanao Akima, Dr.

[Profile]

Shigeo Sato was received his B.E. and Ph.D. degrees from Tohoku University, in 1989 and 1994, respectively. In 1996, he joined the Research Institute of Electrical Communication, Tohoku University. Now, he studies brain computer and quantum computer as a professor.



Towards the Realization of a Prototype Brain Computer

Masao Sakuraba received his B.E. and Ph.D. degrees from Tohoku University in 1990 and 1995, respectively. In 1995, he joined the Research Institute of Electrical Communication, Tohoku University. Now, he studies group IV quantum heterointegration as an associate professor.

[Papers]

[1] “Epitaxial Growth of B-Doped Si on Si(100) by Electron-Cyclotron-Resonance Ar Plasma Chemical Vapor Deposition in a SiH4-B2H6-H2 Gas Mixture without Substrate”, Y. Abe, M. Sakuraba and J. Murota, Thin Solid Films, 557, 10-13, 2014.
[2] “Measurement of large low-order aberrations by using a series of through-focus Ronchigrams”, H. Akima, T. Yoshida, Microscopy, 63, 325-332, 2014.
[3] "Izhikevich neuron circuit using stochastic logic", S. Sato, H. Akima, K. Nakajima, M. Sakuraba, Electronics Letters, 50, 1795-1797, 2014.

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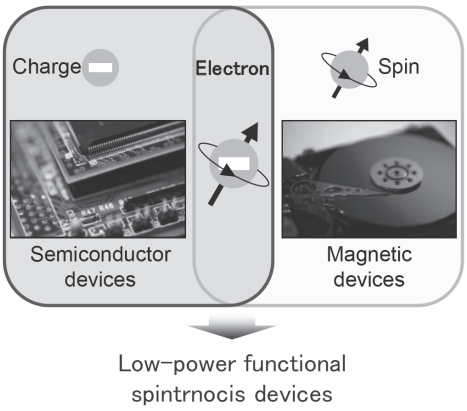
Semiconductor Spintronics

Advanced technology for spintronics-based devices

Functional Spintronics: Hideo Ohno, Professor

[Research Target and Activities]

We are working on spin-related phenomena in semiconductors, magnetic semiconductors, and magnetic metals, as well as novel functional spin materials and devices, in order to realize low-power functional spintronic devices. In particular, we are tackling the following challenges; development of functional spin materials and structures by using molecular beam epitaxy and sputtering, understanding and characterization of spin-related phenomena such as electric field-induced and current-induced magnetization reversal, development of new spintronic devices utilizing them, and fabrication of various prototype integrated circuits employing spintronic devices.



The outcomes in the last fiscal year are (1) clarification of junction size dependence of thermal stability factor and intrinsic critical current in perpendicular-anisotropy magnetic tunnel junctions (MTJs) with double CoFeB-MgO interface down to world's smallest junction diameter of 11 nm, (2) preparation of (Ga,Mn)As with large magnetization by codoping with Li, (3) demonstration of a scheme for magnetization switching in MTJs with two successive voltage pulses to utilize both spin-transfer torque and electric field effect.

[Staff]

Professor: Hideo Ohno, Dr.
Assistant Professor: Michihiko Yamanouchi, Dr.
Assistant Professor: Shun Kanai, Dr.
Research Fellow: Hiroyasu Nakayama, Dr

[Profile of Professor Hideo Ohno]

Hideo Ohno received his Ph. D. degree from the University of Tokyo in 1982. He was with the Faculty of Engineering, Hokkaido University as a Lecturer (1982) and then as an Associate Professor (1983). He moved to Tohoku University in 1994 as a Professor. He received the IBM Japan Science Prize (1998), the IUPAP Magnetism Prize (2003), the Japan Academy Prize (2005), the 2005 Agilent Technologies Europhysics Prize, Thomson Reuters Citation Laureates (2011), JSAP Outstanding Achievement Award (2011), and IEEE David Sarnoff Award (2012). He is Institute of Physics (IOP) Fellow (2004), Honorable Professor at Institute of Semiconductors, Chinese Academy of Sciences, JSAP fellow (2007), and APS fellow (2012), Distinguished Professor at Tohoku University (2008), and IEEE Magnetic Society Distinguished Lecturer for 2009.

[Papers]

[1] H. Sato, E.C.I. Enobio, M. Yamanouchi, S. Ikeda, S. Fukami, S. Kanai, F. Matsukura, and H. Ohno, "Properties of magnetic tunnel junctions with a MgO/CoFeB/Ta/CoFeB/MgO recording structure down to junction diameter of 11nm," Applied Physics Letters **105**, 062403 (2014).

[2] S. Miyakozawa, L. Chen, F. Matsukura, and H. Ohno, "Properties of (Ga,Mn)As codoped with Li," Applied Physics Letters **104**, 222408 (2014).

[3] S. Kanai, Y. Nakatani, M. Yamanouchi, S. Ikeda, H. Sato, F. Matsukura, and H. Ohno, "Magnetization switching in a CoFeB/MgO magnetic tunnel junction by combining spintransfer torque and electric field-effect," Applied Physics Letters **104**, 212406 (2014).

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Nano-Molecular Devices

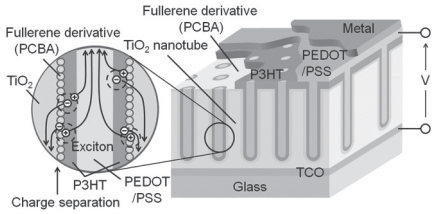
Control of surface and interface of molecular informational devices and development of novel nano-molecular devices

Nano-Molecular Devices: Michio Niwano, Professor

[Research Target and Activities]

Development of the semiconductor nanofabrication technology as typified by photolithography has miniaturized and sophisticated electronic devices. On the other hand, the progress of nanotechnology and biotechnology enables us to synthesize and use biological molecules, supramolecules, and nanostructures with electrically and optically unique features. By combining these technologies, we are aiming to develop molecular scale devices which allow advanced information process.

1. Fabrication of polymer/TiO2-nanotube-based hybrid structures: The incomplete infiltration and non-uniform coating of polymer material in inorganic nanostructures have hindered the applications of hybrid nanostructure. In this work, a novel solvent-vapor-assisted coating (SVAC) method is proposed for uniform coating of polymers in inorganic nanostructure. Hybrid solar cells, made by filling the tube-in-tube structure with hole transporting material, produced drastically improved short circuit current and serial resistance. (Mater. Res. Express)



Hybrid solar cell with TiO_2 nanotube film.

2. Improvement of Electrical Characteristic of P3HT Organic Electrochemical Transistors (OECTs) with Ionic Liquid: We fabricated P3HT OECTs with an ionic liquid by varying conditions of annealing, and investigated effects of annealing temperature and process on the P3HT crystallinity and the characteristics of P3HT OECTs. We found that increasing a crystallinity of an organic active layer by slow cooling in annealing process is crucial to improving electrical characteristic of OECTs.

3. The onset and closure of critical period plasticity regulated by feedforward inhibition: Synaptic circuits are highly sensitive to sensory experience during a critical period in early development. The maturation of GABA inhibition in the visual cortex is suggested to be required for both the onset and closure of the critical period for ocular dominance (OD) plasticity, although the underlying mechanism is unclear. This study examines a model of a visual cortical cell to investigate the mechanism by which inhibitory pathway regulates OD plasticity, through the competition between the groups of correlated inputs from two eyes. (Neurocomputing 143, 261 (2014))

[Staff]

Professor: Niwano, Michio Dr.

[Profile]

Michio Niwano 1998 – present RIEC, Tohoku University, Japan, Professor, Doctorate of Science. Memberships: The Electrochemical Society (ECS), The Japan Society of Applied Physics (JSAP), The Surface Science Society of Japan (SSSJ).

[Papers]

[1] A. Hirano-Iwata, R. Matsumura, R. Tezuka, M. Niwano, T. Bliss, M. Sugawara: "Interference between field excitatory postsynaptic potentials and simultaneously recorded chronoamperometric L-glutamate currents in mouse hippocampal slices", Electrochemistry Communications 45 (2014) 1-4.

[2] I. Sakurai, S. Kubota, M. Niwano, "A Model for Ocular Dominance Plasticity Controlled by Feedforward and Feedback Inhibition", IEICE Transactions on Fundamentals of Electronics Communications and Computer Sciences E97A (2014) 1780-1786.

[3] I. Sakurai, S. Kubota, M. Niwano, "The onset and closure of critical period plasticity regulated by feedforward inhibition", Neurocomputing 143 (2014) 261-268.

[4] Teng Ma, Ryota Kojima1, Daisuke Tadaki, Jinyu Zhang, Yasuo Kimura and Michio Niwano, "Fabrication of polymer/TiO2-nanotube-based hybrid structures using a solvent-vapor-assisted coating method", Materials Research Express 1 (2014) 045048.

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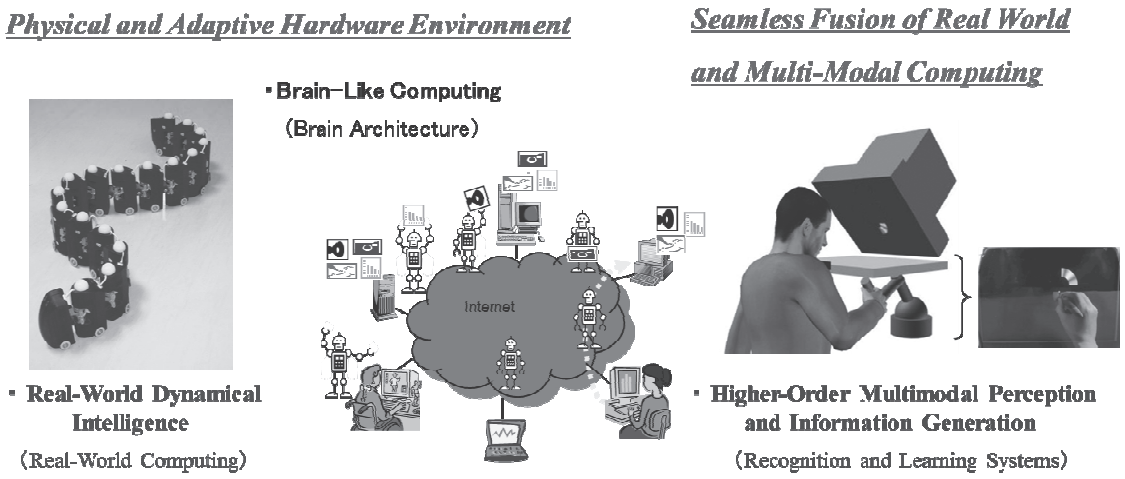
Research Targets and Activities of Laboratory for Brainware Systems

The Laboratory for Brainware Systems of the Research Institute of Electrical Communication was established in 2004 and renewed in 2014. Its purpose is to contribute to the research and development of advanced information science and technology for Brainware systems which realize a seamless fusion of the changeable and complex real world and the cyber space.

We aim at establishing scientific and technological foundations and at exploring human-like brainware computing applications for Adaptive Cognition and Action Systems Division (Recognition and Learning Systems Group), Autonomous Decentralized Control Systems Division (Real-World Computing Group), Brainware LSI Systems Division (New Paradigm VLSI System Group and Intelligent Nano-Integration System Group), and brain architecture Division (planned). The Laboratory for Brainware Systems consists of the above four divisions which cooperatively carry out the research. At the same time they serve as a laboratory for nation-wide cooperative research in the field of Brainware systems.

The technology developed in the Laboratory is expected to enhance the research carried out in the four Divisions of the Institute, and the research conducted in the Divisions, in turn, is expected to provide scientific basis for the information technology developed in the Laboratory.



[Research Target]

Real-World Computing Section: The main contributions achieved in 2014 are summarized as follows: (1) we have proposed a novel measure that can quantitatively measure locomotion patterns of legged animals/robots; (2) we have successfully modeled the inter-arm coordination mechanism underlying ophiuroid locomotion; (3) we have formulated a new decentralized control mechanism for the scaffold-based locomotion of snakes; (4) we have proposed a novel CPG model for bipedal locomotion by exploiting plantar sensation generated by deformable feet; (5) we have proposed a decentralized control mechanism for the interlimb coordination underlying hexapod locomotion.

New Paradigm VLSI System Section: Rapid progress in recent deep submicron regime has led the capability to realize giga-scaled embedded systems on a chip (SoC), while performance degradation of SoCs due to wiring complexity, power dissipation and device-characteristic

variation are increasingly getting serious problems in the recent VLSI chip. Our research activity is to solve the above problems primarily by the following two ways: the use of logic-in-memory architecture based on nonvolatile logic, and the use of asynchronous data-transfer schemes based on multiple-valued current-mode logic, which would open up a novel VLSI chip paradigm, called a "new-paradigm VLSI system."

Intelligent Nano-Integration System Section: Our research activities cover the fields of architectures of Brain computing systems, characterization and application of artificial neural networks, computer aided designs and fabrications of intelligent integrated circuits, and exploitation of new devices for neural circuits. At present research is focused on the large scale integration of Brain computing system and exploitations of new neural devices proposing a neuromorphic quantum computation.

Recognition and Learning Systems Section: Humans can perform various actions based on the recognition of the outside world that is constructed through multiple sensory inputs such as vision and touch, even though they frequently move their own body parts in the environment. Here we investigate the adaptive-process and functions of the human cognitive system for action through psychophysical experiments. On the basis of the experimental evidence, we aim to create computational models of the recognition and learning processes in the human brain.

[Research Activities]

Real-World Computing Section: The main contributions achieved in 2013 are summarized as follows: (1) we have successfully reproduced the versatile gait patterns of quadrupeds and the gait transition between them, e.g., from walk to trot to bound, with real physical robots. To our knowledge, this is the first successful robotic case study that achieves the gait transition ranging from walk to bound gait; (2) we have developed a decentralized-controlled snake-like robot that exhibits omni-directional locomotion. We have also constructed a decentralized control rule that enables concertina locomotion observed in narrow spaces; (3) we have discussed the applicability of our CPG model for quadruped locomotion to bipedal and hexapod locomotion; (4) we have modeled a decentralized control rule that can well reproduce the inter-limb coordination of Ophiuroids. This result could be helpful for realizing resilient robotic systems.

New Paradigm VLSI System Section: The major contributions achieved in 2014 are summarized as follows: (1) a self-terminated write driver for magnetic-tunnel-junction (MTJ) device-based nonvolatile logic LSI is proposed. By optimally monitoring the output voltage of a single MTJ device, a write-completion state has been detected at the minimal delay for writing. The use of dynamic logic-circuit style makes the proposed circuit simple. As a result, 70% of write energy reduction is achieved in comparison with that of a conventional one; (2) a low-power SCN-based search engine LSI is designed and fabricated. Storage elements and search functions are compactly realized using an MTJ-based logic-in-memory (LIM) structure, leading to an 89% energy reduction compared to a conventional counterpart; (3) an MTJ/MOS-hybrid motion-vector prediction LSI is designed and fabricated by using MTJ/MOS-hybrid LSI-oriented automated design flow. The power supply for each processing element is controlled independently cycle by cycle, which achieves 75% wasted power reduction.

Intelligent Nano-Integration System Section: (1) We proposed an inverse function delay-less (IDL) model for high speed numerical calculation of artificial neural networks, and we combined the model with a DS-Net and succeeded to apply to some problems in TSP-LIB with up to 51 cities. (2) We applied an IDL model to back propagation (BP) learning with higher success rate and succeeded to analyze the dynamical operation to explain the solving of local minimum problems in the BP learning. (3) We fabricated a superconducting Schmitt trigger inverter and demonstrated successfully a relaxation oscillator using the inverter.

Recognition and Learning Systems Section: First, we found a motion aftereffect that shows spatial selectivity relative to one's own hand. This finding suggests the existence of neurons that represent spatial location in hand-centered coordinates, which might be useful for guiding movements of one's own body parts. Second, we found that there is the retinotopic process of facial expression in the human brain. Using the face aftereffect, our results showed that the magnitude of the facial-expression aftereffect depends on the retinal distance between adaptor and test. This finding suggests that facial expression information is coded not only in a non-retinotopic visual representation but also in a retinotopic visual representation in the human brain.

Recognition and learning systems laboratory

Understanding the human recognition and learning systems

(Visual Cognition and Systems, Satoshi Shioiri, Professor)
Adaptive Cognition and Action Systems, Kazumichi Matsumiya, Associate Professor
(Auditory and Multisensory Information Systems, Shuichi Sakamoto, Associate Professor)

[Research Target and Activities]

To create computational models of the process that the human brain integrates multiple sensory inputs from the outside world, we are investigating the visual and auditory functions in the human brain for implementing these functions in hardware under biologically plausible settings. Our approaches include psychophysics, brain wave measurements, and computer simulations.

First, we investigated whether a motion aftereffect (MAE) is induced by actively moving a hand that is felt to be one's own. We found that the MAE that shows spatial selectivity in hand-centered coordinates appears only when participants actively move a hand that is seen in front of them. In addition, we found the link between the hand-centered MAE and hand ownership using the rubber hand illusion. These results suggest that sense of owning an actively moved hand generates a perceptual representation of the space encoded in hand-centered coordinates. Second, we investigated whether the characteristic of the retinotopy of the facial aftereffect (FAE) for facial expression is the same as that of the FAE for facial identity. Our results showed that, although dependence of the FAE on adaptation-test distance is similar between facial expression and facial identity, the FAE for facial identity tends to be larger than that for facial expression when a test face is presented in the opposite hemifield. We discussed adaptation mechanisms underlying facial expression processing and facial identity processing.

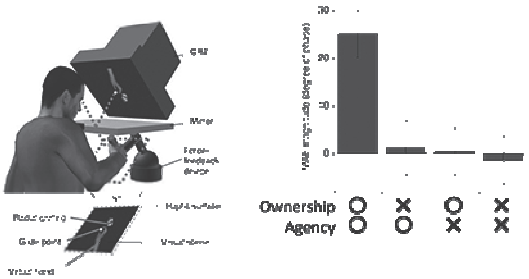


Fig. Senses of hand ownership and agency influence the hand-centered MAE.

[Staff]

Professor : Satoshi Shioiri, Ph.D.
Associate Professor : Kazumichi Matsumiya, Ph.D.
Associate Professor : Shuichi Sakamoto, Ph.D.

[Profile]

Kazumichi Matsumiya, Dr. Matsumiya received Ph.D. degree from Tokyo Institute of Technology in 2000. After then, he worked at Centre for Vision Research, York University in Canada as a postdoctoral fellow. He worked as a researcher at the Imaging Science and Engineering Laboratory, Tokyo Institute of Technology until December, 2003. He worked as a full-time researcher at ATR Human Information Science Laboratories until March, 2005. He joined the Research Institute of Electrical Communication, Tohoku University as a Research Associate in April, 2005. Since then, he has been an Associate Professor from July, 2014.

[Papers]

1. Matsumiya K, Shioiri S: Moving one's own body part induces a motion aftereffect anchored to the body part. Current Biology 24(2), 165-169, 2014.
2. Matsumiya K: Retinotopy of facial expression adaptation. Multisensory Research 27(2), 127-137, 2014.
3. Onizawa N, Katagiri D, Matsumiya K, Gross WJ, Hanyu T: Gabor filter based on stochastic computation. IEEE Signal Processing Letters 22(9), 1224-1228, 2015.

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Intelligent Nano-Integration System

Basic Technology of Integrated System for Intelligent Processing

Intelligent Nano-Integration System, Koji NAKAJIMA, Professor

[Research Target and Activities]

Our research activities cover the fields of architectures of Brain computing systems, characterization and application of artificial neural networks, computer aided designs and fabrications of intelligent integrated circuits, and exploitation of new devices for neural circuits. We also presented a neural system and an FFT operated by using a flux quantum logic in superconducting integrated circuits. At present research is focused on the large scale integration of Brain computing system.

Research Activities in 2014：

(1) We proposed an inverse function delay-less (IDL) model for high speed numerical calculation of artificial neural networks, and we combined the IDL model with a DS-Net and succeeded to apply to some problems in TSP-LIB with up to 51 cities.

(2) We applied an IDL model to back propagation (BP) learning with higher success rate and succeeded to analyze the dynamical operation to explain the solving of local minimum problems in the BP learning.

(3) We fabricated a superconducting Schmitt trigger inverter and demonstrated successfully a relaxation oscillator using the inverter.

[Staff]

Professor：Koji Nakajima, Dr.
Assistant Professor：Takeshi Onomi, Dr.

[Profile]

Koji Nakajima was received his B.E. M.E. and Dr. Eng. from Tohoku University, Sendai, Japan, in 1972, 1975, and 1978, respectively. Since 1978, he has been working at the Research Institute of Electrical Communication, Tohoku University. He is a professor at the same institute of Tohoku Univ., and is currently engaged in the study of VLSI implementation of neural network, and Josephson junction devices for digital applications.

[Papers]

[1] K. Nakajima, “Over View from Josephson Transmission Line to SFQ Logic Circuit and Inverse Function Delay-Less Model ,” Proceedings of Superconducting SFQ VLSI Workshop SSV 2014, pp.8-9, Ookubo Sannomiya Japan, Dec. 2014

[2] Yuta Horiuchi, Yoshihiro Hayakawa , Takeshi Onomi, and Koji Nakajima, “Back Propagation Learning Based on an IDL Model,” Proceedings of the 2014 International Symposium on Nonlinear Theory and its Applications (NOLTA2014), Luzern, Switzerland, Sep. 17, 2014.

[3] Chunyu Bao, Takeshi Onomi , Yoshihiro Hayakawa, Shigeo Sato, and Koji Nakajima, “Performance Analysis of Bidirectional Associative Memories by Using the Inverse Function Delay-less Model,” Proceedings of the 2014 International Symposium on Nonlinear Theory and its Applications (NOLTA2014), Luzern, Switzerland, Sep. 17, 2014.

[4] Takeshi Onomi, “Relaxation Oscillator Using Superconducting Schmitt Trigger Inverter ,” Proceedings of the 2014 International Symposium on Nonlinear Theory and its Applications (NOLTA2014), Luzern, Switzerland, Sep. 17, 2014.

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New Paradigm VLSI System Research Group

Realization of a New-Paradigm VLSI-Computing World

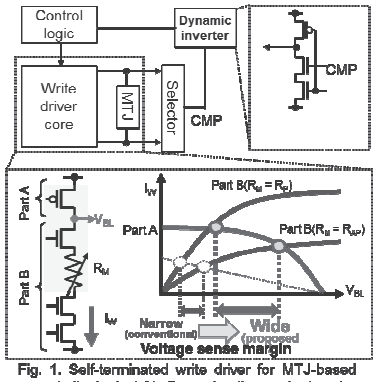

Fig. 1. Self-terminated write driver for MTJ-based nonvolatile logic LSI: By optimally monitoring the output voltage of a single MTJ device, a write-completion state has been detected at the minimal delay for writing. The use of dynamic logic-circuit style makes the proposed circuit simple. As a result, 70% of write energy reduction is achieved in comparison with that of a conventional one.

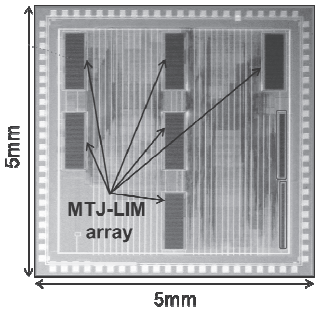

Fig. 2. Low-Power SCN-Based Search Engine LSI: Storage elements and search functions are compactly realized using a magnetic-tunnel-junction (MTJ) based logic-in-memory (LIM) structure, leading to an 89% energy reduction compared to a conventional counterpart.

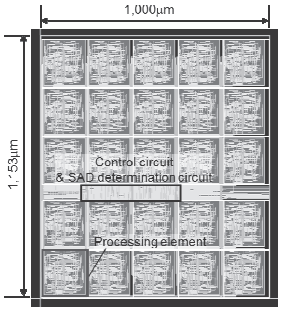

Fig. 3. MTJ/MOS-hybrid motion-vector prediction LSI: The power supply for each processing element is controlled independently cycle by cycle, which achieves 75% wasted power reduction.

New Paradigm VLSI System: Takahiro Hanyu, Professor
New Paradigm VLSI Design: Masanori Natsui, Associate Professor

[Research Target and Activities]

Rapid progress in recent deep submicron regime has led the capability to realize giga-scaled embedded systems on a chip (SoC), while performance degradation of SoCs due to wiring complexity, power dissipation and device-characteristic variation are increasingly getting serious problems in the recent VLSI chip. Our research activity is to solve the above problems primarily by the following two ways: the use of logic-in-memory architecture based on nonvolatile logic, and the use of asynchronous data-transfer schemes based on multiple-valued current-mode logic, which would open up a novel VLSI chip paradigm, called a "new-paradigm VLSI system."

This year, we have succeeded to design MTJ (Magnetic Tunnel Junction)-based low-power VLSIs, such as self-terminated write driver (Fig. 1), search engine LSI (Fig. 2), and motion-vector prediction LSI (Fig. 3).

[Staff]

Professor : Takahiro Hanyu, Dr.
Associate Professor : Masanori Natsui, Dr.
Assistant Professor : Naoya Onizawa, Dr.
Assistant Professor : Daisuke Suzuki, Dr.

[Profile]

Takahiro Hanyu received the D.E. degrees in Electronic engineering from Tohoku University, Sendai, Japan, in 1989. His general research interests include multiple-valued current-mode logic and its application to high performance and low-power arithmetic VLSIs.

Masanori Natsui received the Ph.D. degrees in information Sciences from Tohoku University, Sendai, Japan, in 2005. His research interest includes automated circuit design technique, nonvolatile-based circuit architecture and its application, and design of high speed low-power integrated circuits.

[Papers]

[1] Daisuke Suzuki, et al., "Cost-Efficient Self-Terminated Write Driver for Spin-Transfer-Torque RAM and Logic," IEEE Trans. Magn., vol. 50, no. 11, pp. 3402104~1-3402104~4, Nov. 2014.
[2] Hooman Jarollahi, et al., "A Non-Volatile Associative Memory-Based Context-Driven Search Engine Using 90 nm CMOS/MTJ-Hybrid Logic-in-Memory Architecture," IEEE Journal on Emerging and Selected Topics in Circuits and Systems, vol. 4, no. 4, pp. 460-474, Dec. 2014.
[3] Masanori Natsui, et al., ``Nonvolatile Logic-in-Memory LSI Using Cycle-Based Power Gating and its Application to Motion-Vector Prediction," IEEE Journal of Solid-State Circuits (JSSC), vol. 50, no. 2, pp. 476-489, Feb. 2015.

Real-world Computing

Toward Understanding Design Principle for Life-like Resilient Systems

Real-world Computing Akio Ishiguro, Professor

[Research Target and Activities]

Living organisms exhibit surprisingly adaptive and versatile behavior in real time under unpredictable and unstructured real world constraints. Such behaviors are achieved via spatiotemporal coordination of a significantly large number of bodily degrees of freedom. Clarifying these remarkable abilities enable us to understand life-like complex adaptive systems as well as to construct truly intelligent artificial systems. A prominent concept for addressing this issue is “autonomous decentralized control”, in which non-trivial macroscopic functionalities are emerged via spatiotemporal coordination among vast amount of autonomous components that cannot be explained solely in terms of individual functionality. We study the design principle of autonomous decentralized systems that exhibit life-like resilient behaviors from the viewpoints of robotics, mathematics, nonlinear science, and physics.

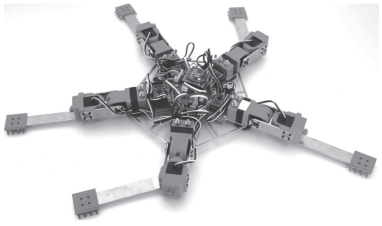

Fig.1: Ophiuroid-like robot that exhibits resilient locomotion.

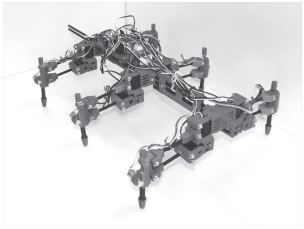

Fig.2: Hexapod robot driven by central pattern generator that well reproduces quadruped gait patterns

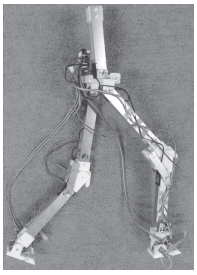

Fig.3: Biped robot with soft deformable feet.

[Staff]

Professor: Akio ISHIGURO, Dr.
Assistant Professor: Dai OWAKI, Dr., Takeshi KANO, Dr., Kazuhiro SAKAMOTO, Dr.

[Profile]

Akio ISHIGURO received B.E., M.E., and Ph.D. degrees from Nagoya University in 1987, 1989, and 1991, respectively. From 1991 to 1997, he was with Nagoya University as an assistant professor. From May 1997 to 2006, he was an associate professor, Nagoya University. From 2006 to 2011, he was a professor of the Graduate School of Engineering, Tohoku University. Since April 2011, he has been a professor of Research Institute of Electrical Communication, Tohoku University. His main research interests are in bio-inspired robotics, nonlinear dynamics. He received 2003 IROS Best Paper Award Nomination Finalist, 2004 IROS Best Paper Award, 2008 Ig Nobel Prize (Cognitive Science Prize), 2009 IROS Best Paper Award Nomination Finalist, 2011 IEEE/RSJ NTF Award Finalist for Entertainment Robots and Systems, Living Machines 2012 Best Paper Award.

[Papers]

[1] T. Kano, D. Owaki, and A. Ishiguro, “A Simple Measure for Evaluating Gait Patterns during Multi-legged Locomotion”, SICE Journal of Control, Measurement, and System Integration, vol. 7, no. 4, pp. 214-218, 2014
[2] T. Kano, H. Date, and A. Ishiguro, "Simple Decentralized Control Scheme Can Reproduce Versatile Gait Patterns of Snakes", The 2014 International Symposium on Nonlinear Theory and its Applications (NOLTA 2014), pp. 20-23, 2014
[3] D. Owaki and A. Ishiguro, "CPG-based Control of Bipedal Walking by Exploiting Plantar Sensation”, 17th International Conference on Climbing and Walking Robots, pp. 335-342, 2014.

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IT-21 center

Research and Development of the IT-Based Practical Technology by the Industry-Academia-Government Collaboration

[Research Target and Activities]

The purpose of the IT-21 center is development of practical technologies for IT based on the advanced technologies of RIEC with the partnership among Industry, Government and University. The term of development is limited less than 5 years. The projects are planed on matching with both basic technologies in the University and application in the Industry. Combination of the technologies of the University and Industry makes practical technologies with availability for the commercial products. The center actively accelerates to obtain the intellectual properties generated from the development of practical technology to the Industry. Presently, two projects for mobile and storage technologies are being carried out.

1. Development of Dependable Wireless System and Devices

Our new project "Development of Dependable Wireless System and Devices" was accepted in 2007 as the Japan Science and Technology Agency (JST) CREST type research program "Fundamental Technology for Dependable VLSI System." The project has been executed by the collaborations between RIEC including IT21 mobile wireless technology group, major Japanese mobile terminal manufacturers and other universities. In this project, concept of Dependable Air, which is multi-mode and multi-band dependable wireless network, is proposed. Within the term until 2014, the project aims at DWS (Dependable Wireless System) wireless terminal, in which transmission distance, communication speed, power consumption, and QoS are all optimized. In 2014 the project attained (1) SS-CDMA communication technology by QZSS location short message synchronization, (2) Research on RF front end module for wide-band communication.

2. Development of High Availability Information Storage Systems

Severe information loss took place due to damage of storage servers at the Tohoku Earthquake. We started research on reliable information storage with smart file backup and restoration, which contributes to anti-disaster information storage technology. A project "Research and Development on highly-functional and highly-available information storage technology" supported by MEXT started in 2012 under the collaborations of RIEC including IT21 storage technology group, Hitachi, a major Japanese Storage manufacturer, and Hitachi Solutions East Japan. The goal of the project is the development of highly functional and highly available storage system. In 2013, (1) A storage system that realizes 90 % of information can be available even when a half (50%) servers are lost or damaged was developed based on the risk-aware algorism, (2) Simulation of high-speed data-transfer was carried out for parallel-track storage device and software defined network systems, (3) Prototyping and testing of the highly reliable storage system.

[Staff]

Director: Hiroaki Muraoka, Professor

Project Planning Division
Makoto Furunishi, Visiting Professor

Technology Development Division (Mobile Wireless Technology Group)
Kazuo Tsubouchi, Visiting Professor
Tadashi Takagi, Visiting Professor

Technology Development Division (Storage Technology Group)
Takaki Nakamura, Associate Professor

IT21 Center Mobile Wireless Technology Group

For Realizing Dependable Air

Kazuo Tsubouchi, Visiting Professor (Project Leader)
Tadashi Takagi, Visiting Professor
Akinori Taira, Associate Professor

[Research Target and Activities]

"Development of Dependable Wireless System and Devices" project was accepted in 2007 as the Japan Science and Technology Agency (JST) CREST type research program.

1. All Si CMOS RFIC: For realizing DWS, we have developed a 5GHz- and 60GHz-band RF circuits using 90nm CMOS technology.
2. Digitally Assisted Compensation Technology: We have developed a novel frequency domain equalizer (FDE) technology implemented to an application specific integrated circuit (ASIC).
3. Adaptive and Scalable ADC/DAC: We have devised a current mode pipeline ADC, which is suitable for process miniaturization and low supply voltage.

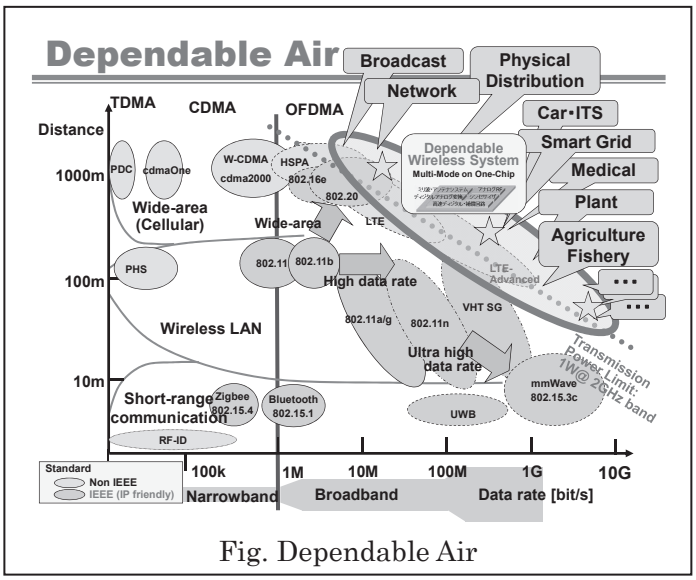

Fig. Dependable Air

[Staff]

Visiting Professor: Kazuo Tsubouchi, Ph. D, Tadashi Takagi, Ph. D

Associate Professor: Akinori Taira, Ph. D

[Profile]

Kazuo Tsubouchi received the Ph.D. degree in Electronics Engineering from Nagoya University in 1974. In 1974, he joined the RIEC. In 1982, he spent at Purdue University as a visiting associate professor. From 1993 to 2010, he has been a professor of RIEC. From 2002 to 2010, he has been the director of IT-21 Center. He is currently a visiting professor. He is a member of the IEEE, the IEICE, the Physical Society of Japan, the Japan Society of Applied Physics, et al.

Tadashi Takagi received the B.S. degree in physics from Tokyo Institute of Technology and Ph.D. degree in electronic engineering from Shizuoka University in 1973 and 1995, respectively. In 1973, he joined the Mitsubishi Electric Corporation, where he was engaged in development on microwave and millimeter-wave circuits technology. From 2005 to 2010, he has been a professor of IT-21 Center. He is currently a visiting professor. He is a fellow of IEICE and a senior member of the IEEE.

Akinori Taira received the B.S., M.S., and Ph.D. degrees in electronics and communication engineering from Waseda University in 1994, 1996 and 2008, respectively. In 1996, he entered the Mitsubishi Electric Corporation, where he had been engaged in research and development of broadband wireless communication system. He is currently an assistant professor of IT-21 Center.

[Papers]

[1] K. Tsubouchi, "Extended Dependable Air: Heterogeneous Wireless Network for Surface, Space and Sea," APMC2014, TH3A-1, Nov. 2014 (Invited).
[2] A. Taira *et al.*, "System Stability of SS-CDMA Location and Short Message Communication Using QZSS," APMC2014, TH3G-24, Nov. 2014.
[3] K. Terajima *et al.*, "A 2.0 GHz CMOS Triple Cascode Push-Pull Power Amplifier with Second Harmonic Injection for Linearity Enhancement," EuMW2014, EuMC/EuMIC01-04, Roma, Oct. 2014.

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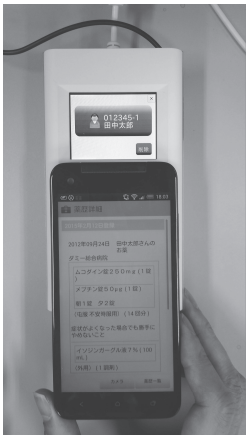
IT21 Center Storage Technology Group

Realization of Highly-available Storage System

Takaki Nakamura, Associate Professor
Hiroshi Matsuoka, Visiting Professor



Application on Smart Phone Working with Highly-Available Storage System

A Snapshot in Field Test of Highly-Available Storage System

[Research Target and Activities]

The Storage Technology Group continue to be engaged in the research and development of storage technology in a collaboration between industry, academia, and government. Our group successfully completed two national projects commissioned by the Ministry of Education, Culture, Sports, Science and Technology from FY2002 to FY2011.

Recently, as social and information systems become more complicated, one of the urgent research areas in storage, in addition to “devices” and “drives”, is the “system”. Because of this our group started a new national project “Research and Development on Highly-functional and Highly-available Information Storage Technology” in FY2012. The project will continue until FY2016. Furthermore, in collaboration with the storage system industry, we will focus on bringing the results of our research into practical use within five years, which is the prime mission of the IT-21 center.

[Staff]

Associate Professor: Takaki Nakamura, Ph.D.
Visiting Professor: Hiroshi Matsuoka, Ph.D.
Research Fellow: Masachika Harada

[Profile]

Takaki Nakamura received B.E, M.E, and Ph.D. in information science from Osaka University in 1996, 1998, and 2011 respectively. He joined Central Research Laboratory, Hitachi, Ltd. in 1998. He is currently an associate professor at RIEC, Tohoku University. He has been engaged in research on storage system.

[Papers]

[1] S. Matsumoto, T. Nakamura, and H. Muraoka, "Risk-based Method for Data Redundancy Determination to Improve Replica Capacity Efficiency," The 3rd Asian Conference on Information Systems (ACIS2014), 2014.
[2] H. Kamei, O. Yashiro, and T. Nakamura, "A Method of Shared File Cache for File Clone Function for Fast Virtual Machine Boot," The 3rd Asian Conference on Information Systems (ACIS2014), 2014.

Contact to Associate Professor Takaki Nakamura : takaki@riec.tohoku.ac.jp

Management Office for Safety and Health

Realizing and Maintaining a Safe and Comfortable Environment to Support Research

[Research Target and Activities]

Safety and health seminar

First aid training course

1. Outline of the Management Office for Safety and Health

The Management Office for Safety and Health is established to maintain the safety and health of students and staff working at the institute. The use of chemicals, high-pressure gas and radiation in research activities at the institute entails many risks. The Management Office for Safety and Health provides support for safety and health management in research laboratories, experimental facilities and the Fundamental Technology Center through various activities to ensure safe and smooth research activities within the institute.

2. Activities by the Management Office for Safety and Health

For the actual management of safety and health at the office, the Safety and Health Committee first presents the basic policies of safety management at the institute, and the Management Office for Safety and Health then plans and executes activities based on them. At the institute, laboratories and other individual sections are highly independent of each other; unlike a general corporate organization, top-down safety management is not suitable and measures appropriate for independent sections need to be taken. Various considerations are also necessary for students, researchers, and other members engaged in research activities as well as faculty staff. At this institute, extremely hazardous materials and facilities are used, including chemicals, high-pressure gas, and X-ray devices. Since there is also a clean room and other special workplaces, safety management should be extended by considering them. In these circumstances, the Management Office for Safety and Health will monitor situations and characteristics in each section at the institute, plan and recommend practical management methods and improvement measures, and support their implementation for the efficient and effective management of safety and health. The main activities in this fiscal year are as follows:

- ○ Holding safety and health seminar and high-pressure gas seminar for staff and students at the institute
- ○ Inspection of and assistance in improving the safety and health management system and working environment within the institute
- ○ Holding first aid training course
- ○ Investigation of laws related to safety and health and collection of information regarding safety and health management
- ○ Providing advice and information to safety and health personnel in each department

[Staff]

Manager: Satoshi Shioiri, Professor

Deputy Manager: Yoichi Uehara, Professor

Nobuyuki Sato, Assistant Professor

Maho Abe, Technical Staff Yoshiko Kikuta, Clerk

anzen@riec.tohoku.ac.jp

Flexible Information System Center

Development and Management of Flexible Information System

[Research Target and Activities]

The present information systems represented by computers are inflexible systems, because their uses are predefined and they provide only the fixed processing and functions. The flexible information system on the other hand, is a system which can perform the flexible information processing adapted to the human intention and situation of its environment beyond the limitations of the principles of the inflexible information processing. The aims of this center are to manage and operate information networks and systems based on the concept of the flexible information system, and support smooth research activities of RIEC.

Figure 1 RIEC network system

Moreover, utilizing technical know-how acquired through applying the information networks and systems to practical use, we also design and construct a leading-edge system for advanced organization, utilization, administration, operation and dispatching of scientific information.

1. Information collection, organization, dispatching, utilization and research support environment.
2. Advanced maintenance, management and operation of network.
3. Technical supports for information networks and systems in the institute.

[Staff]

(1) Steering Committee
Professor: Tetsuo Kinoshita, Dr., Yôiti Suzuki, Dr., Yoshihito Toyama, Dr., Masafumi Shirai Dr., Atsushi Ohori, Dr., Takuo Suganuma, Dr.
(2) FIR Committee
Professor: Yoshihito Toyama, Dr., Takuo Suganuma, Dr.
Associate Professor: Masato Yoshida, Dr., Gen Kitagata, Dr.
Assistant Professor: Takeshi Onomi, Dr., Dai Owaki, Dr., Katsuhiro Ueno, Dr., Kazuto Sasai, Dr.
Technical Official: Masahiko Sato, Kenji Ota
Technical Support Member: Keiko Taniguchi, Yumiko Mishima
(3) Regular Staff
Associate Professor: Gen Kitagata, Dr.
Assistant Professor: Kazuto Sasai, Dr.
Technical Official: Masahiko Sato, Kenji Ota
Technical Support Member: Keiko Taniguchi, Yumiko Mishima

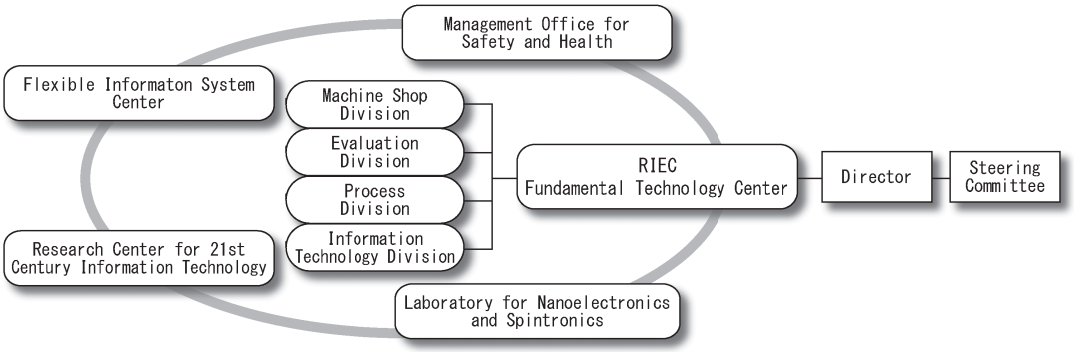
[Profile]

Refer to the Communication Network Laboratory for the profile of Prof. Tetsuo Kinoshita.
Refer to the Computing Information Theory Laboratory for the profile of Prof. Yoshihito Toyama.

Contact to Associate Professor Gen Kitagata : minatsu@fir.riec.tohoku.ac.jp

Fundamental Technology Center

Supporting research with high-level specialized knowledge and technology



Overview of Fundamental Technology Center

[Research Target and Activities]

The Fundamental Technology Center provides a wide range of technical supports for research and development (R & D) through the following four divisions; machine shop, evaluation, process, and information technology. The activities of the present year are summarized as follows except for those of Technical Official F. Saito and Y. Wagatsuma, which are separately described in the sections of Advanced Acoustic Information Systems and Dielectric Nano-devices, respectively.

1. Machine Shop Division

The Machine Shop Division supplied machining products of 96, following requests from researchers. About 20 % of the requests were from the outside of the institute.

2. Evaluation Division

21 laboratories utilized evaluation and measurement apparatuses for shared usage (the utilization time was 5355 hours in total), and furthermore there was utilization from the outside of university. Glass processing products of 9 were supplied. Several services relating to supply of cryogenic liquids were provided.

3. Process Division

This division supplied electron-beam lithographic products of 215, in cooperation with technical office, Laboratory for Nanoelectronics and Spintronics. Technical supports were provided for operating and maintain clean rooms of Laboratory for Nanoelectronics and Spintronics. In addition, optical mutilayered thin films were supplied to the outside of the university.

4. Software Technology Division

This division operated the in-house network at the institute and maintained shared-use-information-equipment, in cooperation with Flexible Information System Center. This division also engaged in contracting affairs of collaborative research based on intellectual-property rights and in giving advices to researchers who tried to apply patents.

[Staff]

Director (Professor): Yoichi UEHARA.

Assistant Professor: Nobuyuki SATO.

Technical Officials: Koichi SHOJI, Tamotsu SUENAGA, Keisuke SATO, Kento ABE, Yasuaki MAEDA, Maho ABE, Takenori TANNO, Tsuyoshi ONOUE, Yurika IWAMI, Iori MORITA, Rikima ONO, Masahiko SATO, Yuko MARUYAMA, Kenji OHTA, Yasuo WAGATSUMA, Shigeto AGATSUMA, Fumitaka SAITO, Katsumi SAGAE, Setsuko ODAGIRI, Toshiko ISHIKAWA, Keiko TANIGUCHI, Yumiko MISHIMA.

Contact to : eac@riec.tohoku.ac.jp

Center for Spintronics Integrated Systems (CSIS)

＜About the Center＞

Establishment：CSIS, which was established on March 10th 2010 in order to implement the FIRST Program, is conducting research and development of ultra-low power spintronics-based VLSIs.

Organization：

・Director ：Hideo Ohno (Professor and Director of RIEC)

・Number of Researchers：25（including 11 concurrent appointments）

Research Target: CSIS has been advancing the following programs to assume a leading role in innovative change by demonstrating the fusion of spintronics devices and logic integrated circuits, thus aiming at playing a pivotal role in the global innovation cycle of VLSIs.

○"Distributed IT system project (project leader : Prof. Hideo Ohno)" in ImPACT program (program manager : Prof. Masashi Sahashi) of CSTI, 2014/10/2～

Research Activities： Research and development of spintronics device, 300mm integration process technology, innovative circuit and the architecture technology, and realization of low power consumption microcontroller driven by energy harvesting

＜Major Achievements in 2014＞

(1) Determination of universality classes of current- and external magnetic field- induced domain wall creep in CoFeB/MgO wire. (2) Demonstration of perpendicular-anisotropy MTJs with double CoFeB-MgO interfaces having capability to withstand annealing at 400°C required for standard back-end-of-line process.

○"Research and Development of Spintronics Material and Device Science and Technology for a Disaster-Resistant Safe and Secure Society (principal investigator: Prof. Hideo Ohno)" under "R&D Program for ICT Key Technology" of MEXT, 2012/8/15～

Research Activities：Research and development of spintronics material and device for high functionality (high speed)/ ultra-low power consumption (high capacity) working memory at technology node of less than 20 nm, and study on simulation of disaster-resistant computer system.

＜Major Achievements in 2014＞

(1) Demonstration of controlling B composition, and thus magnetic properties of CoFeB film in MgO-CoFeB-Ta stack by changing CoFeB and Ta thicknesses as well as annealing condition. (2) Clarification of origin of magnetic anisotropy in Ta/CoFeB/MgO junction by x-ray magnetic circular dichroism. (3) Determination of electric-field modulation ratio of magnetic anisotropy in CoFeB-MgO MTJ by homodyne-detected ferromagnetic resonance and (4) X-band ferromagnetic resonance.

Research Organization of Electrical Communication (ROEC)

Towards Construction of Disaster-Resistant Information Communication Network

[Purpose of our establishment]

Many serious problems have become clear as a result of the Great East Japan Earthquake, which exposed the weaknesses of the most advanced information communications network in the world by severing the mobile phone and optical fiber lines thus cutting off essential telecommunications services. To solve these problems, Tohoku University's Disaster Reconstruction and Regeneration Research Project includes an ICT Reconstruction Project for restoring information communication. The mission given to the researchers in the Electrical Engineering and Information Sciences group after the disaster was to achieve a disaster-resistant information communication network through the ICT Reconstruction Project, taking the needs of the disaster areas into consideration.

To realize this network, we needed to employ the combined strength of our problem-solving abilities by linking researchers in electrical engineering and the information sciences across multiple faculties, including the School of Engineering, the Graduate School of Information Sciences, the Graduate School of Biomedical Engineering, the Cyberscience Center, and the Research Institute of Electrical Communication. These faculties and schools came together to form a new organization that could create close and flexible links between researchers and organizations, and on October 1, 2011 we established the Research Organization of Electrical Communication (ROEC) (Fig.1). The ROEC intends to take an all-Japan approach based on collaboration between industry, academia and government, and assemble expertise from the university with the participation of related local governments, private companies, public research organizations, and other universities with the goal of developing the most advanced disaster-resistant information communication network in the world (Fig.2).

[Main Activities]

Since 2012, we have been promoting 12 disaster-resilient ICT projects supported by the Ministry of Internal Affairs and Communications. In 2014, two ongoing projects were promoted. We have also been engaged in a disaster information delivery project in Cross-ministerial Strategic Innovation Promotion Program (SIP) promoted by the Cabinet Office and a disaster management project supported by RISTEX, JST. In addition, we demonstrated the feasibility of the research results concerning the disaster management system and power ensure in the time of disaster. The research results produced by the promoted projects were presented at the the 3rd United Nations World Conference on Disaster Risk Reduction (WCDRR) held in Sendai on March, 2015, and our activities were described in ROEC Newsletters published in 2014.

Fig.1 Research Organization of Electrical Communication.

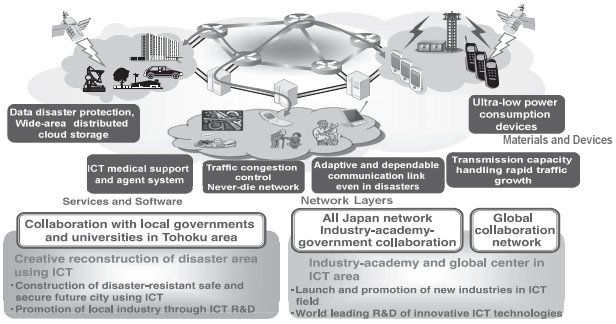


Fig.2 Overview of ICT Reconstruction Project.

[Staff]

Prof. Masataka Nakazawa (Executive Director)
Prof. Fumiyuki Adachi (Vice Executive Director)
Specially Appointed Prof. Naomichi Numata (Vice Executive Director)
Specially Appointed Prof. Katsumi Iwatsuki (Research Administrator)
Mr. Yasuharu Ito (Office Manager)
Mr. Masayuki Kobayashi (Manager)
Ms. Izumi Ishikawa (Secretary)

[Papers]

[1] M. Nakazawa, "Resilient ICT research activities of ROEC at Tohoku University and its cooperation with NICT", IEICE Tech. Rep., vol. 114, no. 287, MWP2014-42, pp. 1-6, Nov. 2014. in Japanese.
[2] F. Adachi, "Recent advances in disaster-resilient multilayered network," IF&E Panel: Disaster-Resilient Networks, 2014 IEEE International Conference on Communications, Sydney, Australia, 11 June, 2014.
[3] Wei Zhao, Zubair Fadlullah, Hiroki Nishiyama, Nei Kato, and Kiyoshi Hamaguchi, "On Joint Optimal Placement of Access Points and Partially Overlapping Channel Assignment for Wireless Networks", IEEE Global Communications Conference 2014 (2014).

Center for Innovative Integrated Electronic Systems (CIES)

＜Overview＞

Establishment: CIES was established in October 2012 to enhance industry-academic collaborations and contribute to the further development of integrated electronic industry. The building was constructed in March 2013 as the first research center by private investment in Science Park at Tohoku University's Aobayama New Campus.

Organization: Director: Tetsuo Endoh (Professor, Graduate School of Engineering)

Number of staff: 64 (including appointments across RIEC, Graduate School of Engineering, Graduate School of Inforamtion Sciences, etc)

Mission: CIES aims to contribute to the enhancement of global competitiveness in the field of next generation integrated electronics systems, and further, work toward the creation of practical applications and new industries, through the research and development of innovative devices and its integrated electronic systems and constructing a consortium for this field under the international collaboration among industries, universities and government.

Research topics: Research and development by industry-university joint research projects, national research projects and so on in a wide variety of integrated electronics fields such as for next-generation semiconductor memory, high-performance printed-circuit board, packaging, and image processing technologies.

＜Major activities in FY2014＞

Toward practical applications from innovative core technologies created by Tohoku University, we managed the international industry-academic consortium (CIES Consortium) consisting of seven industry–academic collaborations, and three major national projects (JST-ACCEL, ImPACT and NEDO projects) through our cooperation with a diverse range of Japanese and foreign companies from fields such as materials, equipment, devices, circuits and systems. CIES produced remarkable results, especially, pronounced achievement to be recognized worldwide with dozens of Japanese and foreign companies participating. Through this our activity, CIES constructed the second such base for collaborative research between industry and academia in the world to be organized by a university for this academic area (other being in the U.S.) with first 300mm wafer process line and facilities for device characterization & physical analysis in Japanese university.

CIES has developed multiple innovative technologies, including next generation memories, high performance board and package technologies, image processing and so on. Especially, Keyshight Technologies, Inc. announced to develop new STT-MRAM test solution based on collaboration with CIES. Thus, some of them have been emerged as the successful results in view of the production phase. These results were presented at 1st CIES Technology Forum on March 2015, in which a total number of 400 participants, and promoted the domestic and international recognitions. CIES established efficient and active academic-industrial collaboration framework, utilizing intellectual property management and operation

system, and safety and stable information security system in order to achieve the best balance between "collaboration synergy" and "information confidentiality" for participant entities during advanced technology R&D activities.

In addition to the R&D activities, the CIES internship program has been conducted, which brought major successes in high-level human resources training. CIES has also been involved in local initiatives designed to help rebuild the Tohoku area and assist the region. CIES consortium's member companies enjoy the benefits of "a special private-sector investment promotion zone system (for information service-related industries)" under a joint application from Miyagi prefecture and local municipalities. Furthermore, these companies can take advantage of a subsidy system that provides "financial assistance according to the amount of property tax paid (created under an agreement between Tohoku University and the city of Sendai)". CIES has also started a technology matching program with regional and local companies.

Spintronics Research and Education Promotion Office

<Overview>

Establishment: December, 2014

Organization:

- Chair of Steering Committee: Executive Vice President (for Research) Sadayoshi Ito
- Steering Committee: 10 members

Mission:

- Discussing the items related to promotion of spintronics R&D in Tohoku University
- Liaison and coordination between relevant departments in Tohoku University

Activities:

(1) Sharing information and innovative technologies on spintronics in Tohoku University

(2) Promotion of spintronics research and training young researchers and students through the collaboration among research groups within and beyond Tohoku University

(3) Establishment of "Center for 'spintronics research innovation and cooperative network' " according to "Basic concept on promotion of large-scale research project －Drawing-up roadmap－ Roadmap 2014"

(4) Other necessary items concerned with spintronics R&D

<Major activities in 2014>

The first Steering Committee was held on January 20, 2015. The content of activities of the Promotion Office was confirmed and the current status of each activity was reported.

The website of the Promotion Office opened in February, 2015 in order to share information on spintronics R&D in Tohoku University. It includes the list of spintronics research groups, the activity of Graduate Program in Spintronics, Tohoku University, and so on.

The request for budgetary appropriations was prepared in order to establish the Center for 'spintronics research innovation and cooperative network'. The main activities of the Center are as follows: (1) accelerating the cooperative research of spintronics devices and integrated systems, (2) contributing the establishment of inter-disciplinary spintronics R&D, (3) creating the technical innovation in collaboration with industry, and (4) developing the next-generation human resource possessing global vision.

Leading Graduate Program
Interdepartmental Doctoral Degree Program for Multi-dimensional Materials Science Leaders

<Overview>

Establishment: October , 2013

Organization:

- Program manager: Executive Vice President (for Education, Student Support and Student International Exchange)Kimio Hanawa
- Program coordinator: Professor Tetsuya Nagasaka (Graduate School of Engineering)
- Program member: about 60 Professors in Tohoku University

Mission:

- Cultivating human resources through creating leaders who have a firm grasp of the fundamentals of material science and extensive research experience
- The term "multi-dimensional" (MD) refers to the extensive, panoramic perception of materials through dimensions such as functionalities, characteristics, processes, environmental compatibility, economics, safety, and assessment techniques.

<Major activities in 2014>

About 20 new students joined the program in 2014. They learned the fundamental and specialized subjects and joined long-term internship at domestic corporations and/or foreign institutions.

The joint symposium co-organized by two Leading Graduate Programs, i.e. MD Program in Tohoku University and Ambitious Leader's Program in Hokkaido University, was held on March 10, 2015 at Tohoku University. Both programs were briefly introduced and research activities are reported. Following to the open symposium, a closed workshop was held. The results of long-term internship are reported by several students at the workshop. After laboratory tour at Advanced Institute for Materials Research, Tohoku University, lectures were given by researchers on March 11, 2015. The joint symposium was a fulfilling occasion for exchange between the students of both programs.

Graduate Program in Spintronics (GP-Spin)

<Overview>

Establishment: April 1, 2015

Organization:

- Program manager: Executive Vice President (for Education, Student Support and Student International Exchange)Kimio Hanawa
- Program leader: Professor Yoshiro Hirayama (Graduate School of Science)
- Program member: about 10 Professors in Tohoku University
- Foreign organization: Johannes Gutenberg Univ. Mainz (Germany), Tech. Univ. München (Germany), Tech. Univ. Kaiserslautern (Germany), Tech. Univ. Delft (The Netherland), Univ. Groningen (The Netherland), Univ. Chicago (USA), Univ. New South Wales (Australia)

Mission:

- Education of world-class leaders in spintronics from fundamental to applications

Activities:

- Education by world-leading professors from all departments and institute in Tohoku University with participation from all over the world
- Joint education with foreign organization including joint supervised degree/joint degree, mutual visit and long-term internship, international school/workshop, qualifying examination to guarantee the educational quality

<Major activities in 2014>

The curriculum and the syllabus of the Graduate Program were prepared in 2014. The selection based on the application requirements were carried out and as a result the first 6 students were selected.

A memorandum for jointly-supervised degree between Tohoku University and Johannes Gutenberg University Mainz was concluded on February 17, 2015.

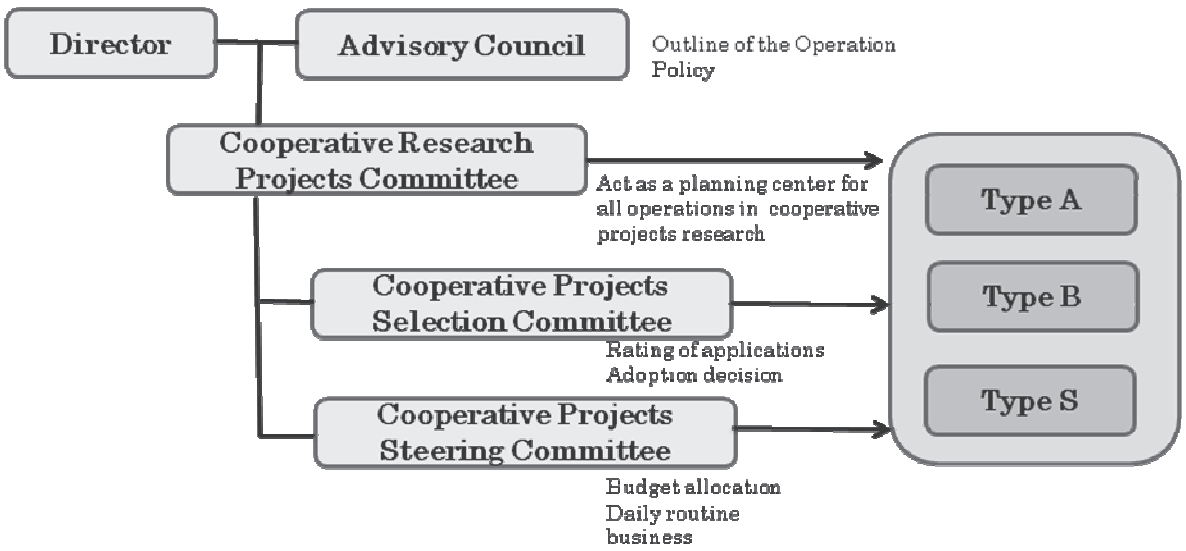
4. Nation-wide Cooperative Research Projects

The Institute has a long history of fundamental contributions in many fields of engineering and science that include the fields of semiconductor materials and devices, magnetic recording, optical communication, electromagnetic technology, applications of ultrasonic, acoustic communication, non-linear physics and engineering, and computer software. On the basis of this rich historical background the Institute was designated as National Center for Cooperative Research in 1994. Accompanying Tohoku University's transformation to "a national university juridical entity" in April,2004, this institution plays a leading role on the world stage, as its researchers, both domestic and foreign, continue the task of "investigating the theory and application of universal science and technology to realize communication, to the enrichment of humanity."

In such background, the Institute organizes Nation-wide Cooperative Research Projects by coordinating its activities with research workers. The main themes for Cooperative Research are selected annually by the Committee for Cooperative Research Projects. Then invitations for project proposals and participation are extended to university faculties and government laboratories as well as industrial research groups. Each project approved by the Faculty Council of the Institute is carried out by a team of researchers that include members of the Institute as well as outside participants.

The advisory Council which includes members from other institutions has an advisory function to the Director in defining the general direction of the research at the Institute and its Nation-wide Cooperative Research Projects.

The Project Selection Committee that includes members from the outside of Tohoku University has a Judging function for project proposals. The purpose of the Project Steering Committee is the proper operation of approved projects.



Nation-wide cooperative research projects list 2014

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H24／A02 Development of Solid Oxide Fuel Cells with Thin Film Electrolyte	**Kiyoshi Uchiyama** Tsuruoka National College of Technology	**Yasuo Cho**
H24／A03 Precise Interface Control of Graphene and Nano Device Applications	**Maki Suemitsu** Research Institute of Electrical Communication, Tohoku University	**Maki Suemitsu**
H24／A04 Basic Study of Plasma Nanobio-Medicine	**Toshiro Kaneko** Graduate School of Engineering, Tohoku University	**Michio Niwano**
H24／A06 Development of Atomically-Controlled Plasma CVD Process for Quantum Heterointegration of Group-IV Semiconductors	**Masao Sakuraba** Research Institute of Electrical Communication, Tohoku University	**Michio Niwano**
H24／A07 Device Design, Evaluation and Preparation of Langasite Family Piezoelectric Single Crystals for High-Temperature Acoustic Sensors at 1000℃	**Yuji Ohashi** Graduate School of Engineering, Tohoku University	**Yasuo Cho**
H24／A10 THz wave generation and detection systems using resonant tunneling devices	**Koichi Maezawa** Graduate School of Science and Engineering for Research, University of Toyama	**Taiichi Otsuji**
H24／A11 Distortion of auditory space caused by vestibular information	**Wataru Teramoto** Muroran Institute of Technology	**Shuichi Sakamoto**
H24／A12 A Fundamental Study on an Affective Networking System	**Masaki Omata** University of Yamanashi	**Gen Kitagata**
H24／A13 Fabrication of artificial lipid bilayers and their application to bio-information devices	**Ayumi Hirano** Graduate School of Biomedical Engineering, Tohoku University	**Michio Niwano**

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H24／A15 Contents-Oriented Computing in Super-distributed Environment	Jun Munemori Faculty of Systems Engineering, Wakayama University	Tetsuo Kinoshita
H24／A16 Research of Coordination Mechanism of Repository-based Multiagent Framework for Symbiotic Computing	Takahiro Uchiya Information Technology Center, Nagoya Institute of Technology	Tetsuo Kinoshita
H25／A01 Fabrication and characterization of nanometer-scale chalcogenide structures, and their application to memory devices	Masashi Kuwahara National Institute of Advanced Industrial Science and Technology	Yoichi Uehara
H25／A02 Study on High-Power Terahertz Signal Source with InGaAs HEMTs	Yohtaro Umeda Tokyo University of Science Faculty of Science and Technology Electrical Engineering	Tetsuya Suemitsu
H25／A03 Self-assembling formation of high density ferromagnetic nanodots by controlled alloying of group IV semiconductors with metals and its magnetic properties	Seiichi Miyazaki Graduate School of Engineering, Nagoya University	Michio Niwano
H25／A04 Electronic structure and properties of ferromagnetic shape memory and other functional magnetic materials	Shin Imada College of Science and Engineering, Ritsumeikan University	Masafumi Shirai
H25／A05 Implementation of Large Scale Superconducting Quantum Detectors for Practical Applications	Satoshi Kohjiro National Institute of Advanced Industrial Science and Technology	Shigeo Sato
H25／A06 High-precision communication system for kansei information of speech	Akihiro Tanaka Tokyo Woman's Christian University	Sakamoto Shuichi
H25／A07 Multi-channel color representation in human brain	Ichiro Kuriki Research Institute of Electrical Communication, Tohoku University	Ichiro Kuriki

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H25／A08 Development of speech processing technology by nonlinear time-varying auditory representation	**Masanori Morise** Interdisciplinary Graduate School of medicine and Engineering, University of Yamanashi	**Shuichi Sakamoto**
H25／A09 Study of the cooperative environment for building visual cognition models	**Ko Sakai** Faculty of Engineering, Information and Systems, University of Tsukuba	**Satoshi Shioiri**
H25／A10 Evaluation of sound field rendering using a surrounding loudspeaker array system	**Takao Tsuchiya** Faculty of Science and Engineering, Doshisha University	**Yôiti Suzuki**
H25／A11 Study of Information Principle of Brainware and its applications	**Toshiyuki Kanoh** NEC Corporation	**Koji Nakajima**
H25／A12 Heterarchical analysis of adaptability under indeterminacy and its technological applications	**Tatsuji Takahashi** School of Science and Engineering, Tokyo Denki University	**Kazuto Sasai**
H25／A13 Interpersonal Communications in a Media Space	**Ikuo Daibo** Motivation and Behavioral Sciences, Tokyo Future University	**Yoshifumi Kitamura**
H25／A15 Study on knowledge acquirement in information networks for agent-based management system	**Yukio Iwaya** Faculty of Engineering, Tohoku Gakuin Univercity	**Tetsuo Kinoshita**
H26／A01 Development of graphene-based electronic and photonic devices	**Takashi Uchino** Tohoku Institute of Technology	**Taiich Otsuji**
H26／A02 Measurement of polarization structure in layered piezoelectric thin films using scanning nonlinear dielectric microscopy	**Hiroyuki Odagawa** National Institute of Technology, Kumamoto College	**Yasuo Cho**
H26／A03 Fabrication of various type high-k/Ge structure by plasma processing and evaluation of their near-interface traps	**Hiroshi Okamoto** Graduate School of Science and Technology, Hirosaki University	**Michio Niwano**

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H26／A04 Development of Fe_4N-based magnetic tunnel junctions with ferroelectric tunnel barrier	**Masakiyo Tsunoda** Graduate School of Engineering, Tohoku University	**Masafumi Shirai**
H26／A05 Studies on fabrication of ferromagnet/semiconductor hybrid structures and their application for spintronics devices	**Fumihiro Matsukura** Advanced Institute for Materials Research, Tohoku University	**Hideo Ohno**
H26／A06 Highly-Strained and Atomically-Controlled Formation of Ge-Based Group-IV Semiconductors and Nanodevice Application	**Masao Sakuraba** Research Institute of Electrical Communication, Tohoku University	**Michio Niwano**
H26／A07 Structure-controlled synthesis and property elucidation of two-dimensional emiconductor material	**Toshiaki Kato** Graduate School of Engineering, Tohoku University	**Satoshi Katano**
H26／A08 Investigation of high sensitive magnetic sensor with Spin-torque-Oscillator	**Yohei Shiokawa** Graduate School of Engineering, Tohoku University	**Satoshi Katano**
H26／A09 Research on fast design method of huge-scale multiband	**Keisuke Konno** Graduate School of Engineering, Tohoku University	**Suguru Kameda**
H26／A10 Development of Wireless Network Architecture for Dependable Air	**Suguru Kameda** Research Institute of Electrical Communication, Tohoku University	**Suguru Kameda**
H26／A11 Study on the organization of cortical circuits	**Shigeru Kubota** Yamagata University	**Michio Niwano**
H26／A12 Reconstruction of neuronal network for generation of hybrid brain	**Haruyuki Kamiya** Hokkaido University Graduate School of Medicine	**Michio Niwano**
H26／A13 Dynamic cues for auditory space perception	**Akio Honda** Yamanashi Eiwa College	**Shuichi Sakamoto**

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H26／A14 Speech intelligibility estimation without transmission characteristics under long-path echo conditions	**Kazuhiro Kondo** Yamagata University	**Shuichi Sakamoto**
H26／A15 Study for thin film functional device obtained by controlling normal magnetic field	**Tomoo Nakai** Industrial Technology Institute, Miyagi Prefectural Government	**Kazushi Ishiyama**
H26／A16 Development of nanostructured hybrid solar cells	**Yasuo Kimura** Tokyo University of Technology	**Teng Ma**
H26／A17 Evaluation of spatial structure and its typology in designing three-dimensional objects using toy blocks with optical illusory patterns	**Tomoko Ohtani** Research Institute of Electrical Communication, Tohoku University	**Tomoko Ohtani**
H26／A18 Application of 3D Interactive Technologies to Medical Education based on the Method of Design	**Yoshifumi Kitamura** Research Institute of Electrical Communication, Tohoku University	**Yoshifumi Kitamura**
H26／A19 A study on new information processing technology focusing on the flow of information	**Keiichi Yasumoto** Nara Institute of Science and Technology	**Gen Kitagata**
H26／A20 Study on Cooperative Mechanism of Sympathetic Devices for Mental Status Sharing	**Tatsuya Yamazaki** Niigata University	**Hideyuki Takahashi**
H26／A21 An accurate estimation for acoustical transfer function of pinna from camera images	**Masashi Itoh** Tohoku Institute of Technology	**Shuichi Sakamoto**
H26／A22 Study of magnetic coupling and spin transport mechanisms in magnetic semiconductors and oxides	**Fumihiro Matsukura** Advanced Institute for Materials Research, Tohoku University	**Hideo Ohno**
H26／A23 Japan-Spain International Research Collaboration on Terahertz Sensing Devices	**MEZIANI Yahya Moubarak** University of Salamanca	**Taiichi Otsuji**

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H26／A24 Study on Direct Digital RF MODEM Technologies	**Noriharu Suematsu** Research Institute of Electrical Communication Tohoku University	**Noriharu Suematsu**
H26／A25 Cultural and individual differences in color lexicon	**Keiji Uchikawai** Tokyo Institute of Technology	**Satoshi Shioiri**
H26／A26 Machine Learning Hand-Manipulation for HCI Application	**Taku Komura** University of Edinburgh	**Yoshifumi Kitamura**
H26／A27 A Novel Development for 3D Natural User Interfaces	**Yoshifumi Kitamura** Research Institute of Electrical Communication Tohoku University	**Yoshifumi Kitamura**
H24／B01 Fundamental characteristics and applications in innovative functional and reactive field generated with various plasma flow	**Akira Ando** Graduate School of Engineering Tohoku University	**Maki Suemitsu**
H24／B02 Unlicensed Band Wireless Communications	**Shuzo Kato** Research Institute of Electrical Communication Tohoku University	**Shuzo Kato**
H24／B03 Problems and perspectives of intelligent nano integrated system	**Yoshihiro Hayakawa** Sendai National College of Technology	**Koji Nakajima**
H24／B05 Entertainment Computing for Creative Rejuvenation	**Yoshifumi Kitamura** Research Institute of Electrical Communication Tohoku University	**Yoshifumi Kitamura**
H24／B06 A New Academic Association for HCI in the Asia-Pacific Region	**Yoshifumi Kitamura** Research Institute of Electrical Communication Tohoku University	**Yoshifumi Kitamura**
H24／B07 Functionalization of oxide surfaces and its application to nanodevices	**Toshio Ogino** Graduate School of Engineering Yokohama National University	**Michio Niwano**
H24／B08 Research on planar measurement techniques for earthquake, tsunami, and crustal deformation using optical-fiber networks	**Masato Araya** Earthquake Research Institute, The University of Tokyo	**Masataka Nakazawa**

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H24／B10 Computational Ability of High-Dimensional Neural Network	**Akira Hirose** Graduate School of Engineering, The University of Tokyo	**Shigeo Sato**
H24／B11 Study of human perceptual/cognitive and decision processes	**Ken-ichiro Tsutsui** Graduate School of Life Sciences, Tohoku University	**Satoshi Shioiri**
H24／B12 Evolution of elementary technologies of high performance Computing for national security needs	**Yoshihiko Orita** Japan Marine Science Fundation	**Takahiro Hanyu**
H24／B13 Studies on enrichment technologies for digital contents	**Akira Nishimura** Tokyo University of Information Sciences	**Yôiti Suzuki**
H25／B01 New Principle Nano Devices Based on Precision Control and Observation of Spin Fluctuation and Correlations	**Shintaro Nomura** Graduate School of Pure and Applied Sciences, University of Tsukuba	**Hideo Ohno**
H25／B02 Fabrication of novel nano-materials based on fine particle plasma physics	**Masaharu Shiratani** Graduate School and Faculty of Information Science and Electrical Engineering, Kyushu University	**Michio Niwano**
H25／B03 Research in magnetic materials and magnetic devices for advanced communications equipment	**Takeshi Yanai** Graduate School of Engineering, Nagasaki University	**Kazushi Ishiyama**
H25／B04 Physics and applications of electric-field control of magnetism	**Masafumi Shirai** Research Institute of Electrical Communication, Tohoku University	**Masafumi Shirai**
H25／B05 Novel photonics and nano photonic informatic	**Takashige Omatsu** Graduate School of Advanced Integration Science, Chiba University	**Keiichi Edamatsu**

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H25／B06 Research on Electromagnetic Wave Technologies for Low-Carbon Energy Society	Takashi Ohira Toyohashi Univercity of Technology	Noriharu Suematsu
H25／B07 Studies on cortical mechanisms for visual perception of object-surface attributes	Katsunori Okajima Yokohama National University Graduate School of Environment and Information Sciences	Ichiro Kuriki
H25／B08 Understanding of human adaptive motor function based on the concept of embodiment	Toshiyuki Kondo Tokyo University of Agriculture and Technology	Akio Ishiguro
H25／B09 Development and Civilian Use of Microwave and Laser Aided Synthetic Aperture Radar	Yuichiro Kogi Fukuoka Institute of Technology	Hiroshi Yasaka
H25／B10 Logical Approach to Metaprogramming	Yukiyoshi Kameyama Graduate School of Systems and Information Engineering, University of Tsukuba	Yoshihito Toyama
H26／B01 Study of functional piezoelectric materials and applications to advanced communication devices	Shin-ichiro Umemura Graduate School of Biomedical Engineering Tohoku University	Yôiti Suzuki
H26／B02 Research on the new concept devices with integration of nano materials on silicon technology	Heiji Watanabe Graduate School of Engineering, Osaka University	Hideo Ohno
H26／B03 Research for future electronic systems by nano devices and circuits with nano semiconductor materials	Kikuo Yamabe Graduate School of Pure and Applied Sciences University of Tsukuba	Hideo Ohno
H26／B04 Microwave magnetic materials and application to nano information devices	Masahiro Yamaguchi Graduate School of Engineering, Tohoku University	Kazushi Ishiyama
H26／B05 Hybrid Semiconductor Circuit Technologies and Their Applications for Next Generation RFICs	Kenjiro Nishikawa Graduate School of Science and Engineering, Kagoshima University	Noriharu Suematsu

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H26／B06 Advanced Communication and Measurement Systems Using Coherent Multicarrier Lightwave	Hidemi Tsuchida National Institute of Advanced Industrial Science and Technology	Masataka Nakazawa
H26／B07 KOTO-mimetics: Rethinking and Recreating Biomimetics	Koichi Oosuka Graduate School of Engineering, Osaka University	Akio Ishiguro
H26／B08 Contribution of self-body motion to multisensory integration	Kenzo Sakurai Faculty of liberal arts. Tohoku Gakuin University	Yôiti Suzuki
H26／B09 International Research Collaboration of Brainware LSI	Takahiro Hanyu Research Institute of Electrical Communication Tohoku University	Takahiro Hanyu
H26／B10 Reliable and Scalable Foundation for Parallel Computing on Many-Core Architecture	Kazuhiko Kato Graduate School of Systems and Information Engineering University of Tsukuba	Atsushi Ohori
H26／B11 Sensing and Communication Technologies for Human and Mobility	Takeshi Oishi Institute of Industrial Science, the University of Tokyo	Kazuki Takashima
H24／S1 Empathic Computing System based on an innovative new concept associated with human functions	Takashi Washio The Institute of Scientific and Industrial Research (ISIR) Osaka University	Yoshifumi Kitamura
H26／S1 Project to construct the basis for future science and technology of coherent wave	Hidenori Mimura Research Institute of Electronics, Shizuoka University	Hiroshi Yasaka
H26／S2 Spintronics Academic Alliance	Masaaki Tanaka Graduate School of Engineering, The University of Tokyo	Masafumi Shirai
H26／S3 Collaborative Research on Nano-electronics	Tetsuya Osaka Institute for Nanoscience & Nanotechnology, Waseda University	Michio Niwano

5. Symposium organized by the Institute

This Symposium is planned to exchange relevant information on current important topics concerning Electrical Eng., Electrical Communications, Electronic Eng., and Information Eng. Many related researchers inside and outside Tohoku University participate the Symposium and stimulate discussion.

Symposium In Past

	Title	Date
1	Quantum Electronics of Liglht Waves and Micro Waves	Feb. 6- 8, 1964
	Magnetic Recording	Feb.14-15, 1964
2	Ultra-High Frequency Acoustelectronics	Feb.11-12, 1965
3	Artificial lntelligence	Mar. 8- 9, 1966
4	Thin Film Electronics	Jan.26-27, 1967
5	Crystal Growth	Dec. 19-20, 1967
6	1968 Sendai Svmoosium on Acoustelectronics	Aug.19-20, 1968
7	Current Status and Future Trends of Superconductivitv	Jan.22-24, 1970
8	Soeech Information Processing	Feb.24-26, 1971
9	Surface Acoustic Wave Technology	May.25-26, 1972
10	Liquid Crystals ·Their Molecular Orientations and Application to Display Devices	Dec.13-14, 1974
11	Computer Network	Mar.17-18, 1975
12	The Memorial Symposium on the 40th Anniversarv of the Foundation of RIEC	Sep.25-26, 1975
13	Application of Amorphous Ferromagnetic Materials	Mar.10-11, 1977
14	Stoichiometry of Compound Crystals	Nov.24-25, 1977
15	Submillimeter Waves	Nov.16-17, 1978
16	Solid State Chemical Sensors	Feb. 1- 2, 1980
17	Graph Theory and Algorithms	Oct.24-25, 1980
18	Perpendicular Magnetic Recording	Mar.11-12, 1982
19	Approach to Optical Computer	Mar.10-11, 1983
20	Plasma Non-Linear Phenomena - Basic Problems for Fusion Plasmas	Mar. 8- 9, 1984
21	New Computer Architecture	Jul.25-26, 1985
22	Guided Wave Technology and Its Application at Mid-Infrared	Mar.13-14,1986
23	Physics and Applications of Tunnelling Phenomena	Mar.12-14, 1987
24	Biomagnetics and Bioelectronics	Feb.26-27, 1988
25	Ultrasonic Electronics - New Applications of Piezoelectricity	Feb. 2- 3, 1989
26	Boundaries between Light and Electromagnetic Wave	Feb. 1-2, 1990

27	Issues and Realization of Pattern Recognition and Understanding	Feb.28-Mar.1,1991
28	Discrete Algorithms	Oct.17-18, 1991
29	Perspective for New Computing Paradigm	Feb. 4- 5, 1993
	Current Status and Future Prospects of System Control	Mar. 3- 4, 1993
30	Future Prospects of Electron Beam Devices	Nov. 1- 2, 1993
31	Discharge and EMC	Dec.20-21, 1994
32	Statistical Physics and Information Science	Mar.22-23,1995
33	Photo-and Plasma-Excited Processes on Surfaces	Nov.30-Dec.1,1995
34	Nano Spinics and Power Electronics	Feb.15-16, 1996
35	Potential Formation and Related Nonlinear Phenomena in Plasmas	Sep.17-19, 1996
36	New Trend in Ultrasonic Measurements	Feb. 3- 4, 1997
37	Toward the Realization of the High-Definition Multi-Media Communication	Nov. 4- 6, 1997

International Symposium Organized by the Institute

	Title	Date
1	Intrinsic Josephson Effect and THz Plasma Oscillation in High T_c Superconductors	Feb.23-25, 1997
2	Design and Architecture of Information Processing Systems Based on The Brain Information Principle	Mar.16-18, 1998
3	Novel Techniques and Applications of Millimeter-Waves	Dec.14-16, 1998
4	The International Joint Conference on Silicon Epitaxy and Heterostructures	Sep.13-17, 1999
5	International Workshop on Photonic and Electromagnetic Crystal Structures	Mar.8-10, 2000
6	Physics and Application Spin Related Phenomena in Semiconductors	Sep.13-15, 2000
7	Rewriting in Proof and Computation	Oct.25-27, 2001
8	Nonlinear Theory and its Applications	Oct.28-Nov.1, 2001
9	New Paradigm VLSI Computing	Dec.12-14, 2002
10	Ultra High Density Spinic Storage System	Oct.23-24, 2003
11	3rd International Workshop on New Group IV (Si-Ge-C) Semiconductors	Oct.12-13, 2004
12	3rd International Workshop on High Freaqency Micromagnetic Devices and Materials (MMDM3)	Apr.11-12, 2005
13	4th International Conference on Silicon Epitaxy and Heterostructures (lCSl-4)	May.23-26, 2005
14	1st International WorkShop on New Group IV Semiconductor Nanoelectronics	May.27-28. 2005
15	GSIS International Symposium on Information Sciences of New Era: Brain, Mind and Society	Sep.26-27, 2005
16	The 1st RIEC International Workshop on Spintronics -Spin Transfer Phenomena-	Feb.8-9, 2006
17	4th International Workshop on High Frequency Micromagnetic Devices and Materials (MMDM4)	May 8,2006
18	4th International Conference on Physics and Applications of Spin-Related Phenomena in Semiconductors (PASPS-lV)	Aug.15-18,2006
19	2nd International Workshop on New Group IV Semiconductor Nanoelectronics	Oct.2-3,2006
20	2nd RIEC International Workshop on Spintronics	Feb.15-16,2007
21	Japan-China Joint Conference on acoustics, JCA2007	Jun.4-6,2007
22	International Conference on Discovery Science/ International Conference on Algorithmic Learning Theory	Oct.1-4,2007

23	The 3rd RIEC International Workshop on Spintronics	Oct. 31-Nov.1,2007
24	3rd International Workshop on New Group Ⅳ Semiconductor Nanoelectronics	Nov.8-9,2007
25	International Workshop on Nanostructures & Nanoelectronics	Nov.21-22,2007
26	The 18th International Symposium on Algorithms and Computation(ISAAC2007)	Dec.17-19,2007
27	International Interdisciplinary-Symposium on Gaseous and Liquid Plasmas (ISGLP 2008)	Sep.5-6,2008
28	4th International Workshop on New Group IV Semiconductor Nanoelectronics	Sep.25-27,2008
29	The 4th RIEC International Workshop on Spintronics	Oct.9-10,2008
30	Global Symposium on Millimeter Waves 2009 (GSMM2009)	Apr.20-22,2009
31	Mini R.I.E.C. workshop on multimodal perception	Apr.24,2009
32	The 4th International Symposium on Ultrafast Photonic Technologies	Aug.4-5,2009
33	PIMRC2009 Personal Indoor and Mobile Radio Communications Symposium 2009	Sep.13-16,2009
34	2nd RIEC-CNSI Workshop on Nanoelectronics,Spintronics and Photonics (5th RIEC Symposium on Spintronics)	Oct.22-23,2009
35	International Workshop on the principles and applications of spatial hearing 2009 (IWPASH2009)	Nov.11-13,2009
36	5th International Workshop on New Group IV Semiconductor Nanoelectronics	Jan.29-30,2010
37	6th RIEC International on Spintronics	Feb.5-6,2010
38	2nd International Workshop on Nanostructure & Nanoelectronics	Mar.11-12,2010
39	2nd RIEC International Symposium on Graphene Devices (ISGD2010)	Oct.27-29,2010
40	9th Japan-Korea Symposium on Surface Nanostructures	Nov.15-16,2010
41	The 7th RIEC International Workshop on Spintronics	Feb.3-4,2011
42	The 42nd RIEC International Symposium 12th International Multisensory Research Forum (IMRF2011)	Oct.17-20,2011
43	The 8th RIEC International Workshop on Spintronics	Feb.2-3,2012
44	The Sixth International Symposium on Medical, Bio- and Nano-Electronics	Mar.8,2012
45	3rd International Workshop on Nanostructures & Nanoelectronics	Mar.21-22,2012
46	9th RIEC International Workshop on Spintronics	May.31-Jun.2,2012
47	The 1st International Workshop on Smart Technologies for Energy, Information and Communication (STEIC2012)	Oct.18-19,2012
48	Technical University of Dresden and Tohoku University Symposium 2012	Nov.2,2012

49	The 1st RIEC International Symposium on Brain Functions and Brain Computer	Nov.15-16,2012
50	Tohoku – Harvard Joint Workshop New Directions in Materials for anoelectronics,Spintronics and Photonics （10th RIEC International Workshop on Spintronics）	Jan.15-16,2013
51	11th RIEC International Workshop on Spintronics & 3rdCSISInternationalSymposiumonSpintronics-based VLSIs	Jan.31-Feb.1,2013
52	7th International Symposium on Medical, Bio- and Nano-Electronics	Mar.7,2013
53	6th Global Symposium on Millimeter Wave 2013	Apr.22-23,2013
54	The 2nd RIEC International Symposium on Brain Functions and Brain Computer	Feb.21-22,2014
55	8th International Symposium on Medical,Bio- and Nano-Electro	Mar.6-7,2014
56	5th International Workshop on Nanostructures and Nanoelectronics	Mar.6-7,2014
57	12th RIEC International Workshop on Spintronics	Jun.25-27, 2014
58	The IEEE International Conference on Microwave Magnetics	Jun.29-Jul.2,2014
59	RIEC International Symposium on Perception and Communication	Jul.24,2014
60	APMC 2014(2014 Asia-Pacific Microwave Conference)	Nov.4-7,2014
61	The 3rd RIEC International Symposium on Brain Functions and Brain Computer	Feb. 18-19,2015
62	International Symposium on Brainware LSI	Mar.2-3,2015
63	The 9th International Symposium on Medical, Bio- and Nano-Electronics	Mar.2-4,2015
64	The 6th International Workshop on Nanostructures and Nanoelectronics	Mar.2-4,2015
65	RIEC International Symposium on Vision and Cognition	Mar.20,2015

6. Study Groups on Electrical Communication

Study Groups on Electrical Communication are organized to solve scientific and technological problems and to promote research and development through the collaboration of the Research Institute of Electrical Communication, Depts. of Electrical Eng., Electrical Communications, Electronic Eng., Information Eng., and related scientists and engineers inside and outside Tohoku University. The Study Groups on Electrical Communication consist of 15 Sub-Groups as listed below, to deal with specific subjects. Each Sub-Group holds workshops. The abstracts of the workshops are published annually in *The Record of Electrical and Communication Engineering Conversazione Tohoku University*.

Many scientists and engineers—not only from universities but also from government laboratories and industries—attend the workshops, present papers, and discuss issues actively. We are pleased to provide information on these activities upon request. Please contact each Sub-Group Chairman or manager for general information or more specific questions.

Electromagnetic and Optical Waves Engineering	
Chair	Prof. Chen Qiang
Manager	Assistant Prof. Keisuke Konno

Acoustic Engineering	
Chair	Prof. Akinori Ito
Manager	Associate Prof. Shuichi Sakamoto
Manager	Lecturer Takashi Nose

Sendai "Plasma Forum"	
Chair	Prof. Akira Ando
Manager	Prof. Toshiro Kaneko

Sendai Seminar on EMC	
Chair	Prof. Hideaki Sone
Manager	Prof. Masahiro Yamaguchi

Computer Science	
Chair	Prof. Ayumi Shinohara
Manager	Associate Prof. Eijiro Sumii

Systems Control	
Chair	Prof. Makoto Yoshizawa
Manager	Associate Prof. Norihiro Sugita

Information-biotronics	
Chair	Prof. Tatsuo Yoshinobu
Manager	Associate Prof . Ayumi Hirano

Spinics	
Chair	Prof. Hidetoshi Matsuki
Manager	Associate Prof. Masakiyo Tsunoda
Manager	Assistant Prof. Sho Muroga

New Paradigm Computing	
Chair	Prof. Takahiro Hanyu
Manager	Associate Prof. Naofumi Homma

Ultrasonic Electronics	
Chair	Prof. Shin-ichiro Umemura
Manager	Associate Prof . Shin Yoshizawa

Brainware	
Chair	Prof. Akio Ishiguro
Manager	Assistant Prof. Takeshi Kanou

Mathematical Physics and its Application to Information Sciences	
Chair	Prof. Kazuyuki Tanaka
Manager	Associate Prof. Yuji Waizumi

Biocybernetics and Bioinformatics	
Chair	Prof. Satoshi Shioiri
Manager	Associate Prof. Takeshi Obayashi

Nanoelectronics and Spintronics	
Chair	Prof. Shigeo Sato
Manager	Prof . Michio Niwano

Advenced Information Communication Engineering	
Chair	Prof. Tetsuo Kinoshita
Manager	Associate Prof. Gen Kitagata

7. International Activities

Many of the staff in RIEC contribute to the development of technology and science in the world by serving as editors of referees of international journals or by chairing or programming international conferences. In some fields in electronics, electrical communications, or information engineering RIEC serves as a Center of Excellence (COE), which attracts many visiting researchers and students from all over the world every year. Several academic exchange programs with foreign colleges or institutes are in operation.

International academic exchange programs:

- The Institute of Physics, Polish Academy of Sciences (Poland)
- ＊The Faculty of Science, Chulalongkorm University (Thailand)
- ＊Harbin Institute of Technology (China)
- ＊The James Frank Institute, The University of Chicago (U.S.A.)
- ＊Queen Mary and Westfield College, University of London (U.K.)
- ＊Scientific Research Department, Shenzhen University (China)
- ＊Institute of Information and Communication Technology, Sung-Kyun-Kwan University (Korea)
- ＊Institute of Materials Science, Faculty of Applied Physics, University of Twente (Netherlands)
- ＊The Institute of Radioengineering and Electronics Russian Academy of Sciences (Russia)
- ＊Department of Electronics Science and Engineering, University of Nanjing (China)
- ＊School of Computer and Communication Engineering, Taegu University (Korea)
- The Interdisciplinary Center on Nanoscience of Marseille, National Center of Scientific Research (France)
- IHP-Innovations for High Performance Microelectronics (Germany)
- Institute of Semiconductors Chinese Academy of Sciences (China)
- WINLAB, Rutgers University (U.S.A.)
- University of Vigo (Spain)
- State University of New Nork, College of Nanoscale Science and Engineering(CNSE)(U.S.A)
- Department of Physics, National Sun Yat-Sen Univesity (Taiwan)
- Research and Educational Center "Photonics and Infrared Technology" and Institute of Radio Electronics and Laser Technology , Bauman Moscow State Technical University (Russia)
- Research Laboratory of Electronics and Microsystems Technology Laboratories, Massachusetts Institute of Technology(MIT)(U.S.A.)

(＊: expired program)

International journals in which a staff in RIEC participates as an editor:

1	Acoustical Science and Technology
2	Advanced Robotics
3	Applied Intelligence
4	Chinese Journal of Acoustics
5	Frontiers in Virtual Environments (a section of Frontiers in Robotics and AI)
6	IEEE Magnetics Letter
7	IEICE Electronics Express
8	International Journal of Distributed Sensor Networks (IJDSN)
9	International Journal of Energy, Information and Communication

10	Japanese Journal of Applied Physics
11	IET Nicrowaves, Antenna & Propagation
12	Journal of Magnetics, Korean Magnetics Society
13	Journal of SPIN
14	Nature Communications
15	Neural Networks
16	Nonlinear Theory and Its Applications, ZEZCE
17	NPG Asia Materials
18	Optical Fiber Technology
19	Optical Review
20	Scientific Reports
21	The Journal of Computer Animation and Virtual Worlds (John Wiley & Sons, Inc.)

Recent international conferences programmed by a staff in RIEC

1	14th European Conference Physics of Magnetism 2014 (PM'14)
2	32nd International Conference on Physics of Semiconductors (ICPS2014)
3	ACM Conference on Human-Agent Interaction (HAI 2014)
4	ACM SIGGRAPH Asia
5	ACM SIGGRAPH Asia 2014: The 7th SIGGRAPH Conference and Exhibition on Computer Graphics and Interactive Techniques in Asia 2014
6	ACM SIGGRAPH Asia 2015: The 8th SIGGRAPH Conference and Exhibition on Computer Graphics and Interactive Techniques in Asia 2015
7	ACM Symposium on Satial User Interfaces (SUI 2014)
8	ACM Symposium on Virtual Reality Software and Technology (VRST 2014)
9	ACM Symposium on Virtual Reality Software and Technology (VRST)
10	APMC: Asia-Pacific Microwave Conference
11	Asia-Pacific Conference on Vision (APCV) 2015
12	Asia-Pacific Workshop on Fundamentals and Applications of Advanced Semiconductor Devices (AWAD)
13	EUMC (European Microwave Conference)
14	Eurographics Workshop on Virtual Environment (EGVE)
15	European Conference on Optical Communication (ECOC)
16	European Solid-State Device Research Conference (ESSDERC)
17	IEEE Global Conference on Consumer Electronics (GCCE2015)
18	IEEE International Microwave Symposium (IEEE IMS)
19	IEEE International Symposium on Asynchronous Circuits and Systems
20	IEEE International Symposium on Multiple-Valued Logic
21	IEEE Symposium on 3D User Interfaces (3DUI)
22	IEEE Symposium on 3D User Interfaces (3DUI 2014)
23	IEEE/WIA/ACM International Joint Conference of Web Intelligence and Intelligent Agent Technologies (WI-IAT2015)
24	IFIP (International Federation for Information Processing)
25	INTERMAG
26	International Conference Industrial & Eingineering Applications of Artificial

	intelligence & Expert Systems (IEA/AIE-2015)
27	International Conference on Artificial Reality and Tele-existence (ICAT)
28	International Conference on Electron Dynamics in Semiconductors, Optoelectronics and Nanostructures (EDISON)
29	International Conference on Indium Phosphide and Related Materials (IPRM)
30	International Conference on Recent Progress in Graphene Research (RPGR)
31	International Conference on Superlattices, Nanostructures and Nanodevices (ICSNN)
32	International Conferences on Modern Materials & Technologies (CIMTEC)
33	International Symposium on Compound Semiconductors (ISCS)
34	Magnetism and Magnetic Materials(MMM)
35	Opto-Electronics and Communications Conference (OECC)
36	SPIE International Conference on Defense, Security, and Sensing
37	Spintronics Workshop on LSI
38	Technical Committee of Multiple-Valued Logic, IEEE Computer Society
39	The Tenth International Conference on Intelligent Information Hiding and Multimedia Signal processing (IIH-MSP-2014)
40	The25th IEEE Semiconductor Laser Conference (ISLC)2016
41	Topical Workshop on Heterostructure Microelectronics (TWHM)

8. Periodicals Published by the Institute

The Institute publishes the following two periodicals to inform readers on recent research results of the Institute.

1. The Record of Electrical and Communication Engineering Conversazione Tohoku University

This journal aims at providing an opportunity to publish research results of the Institute as well as the result of the Graduate School of Engineering, Information Sciences, Biomedical Engineering. Since the journal also aims at publishing general research activities of the Institute and of the Graduate School such as records of the final lectures of retiring professors, records of the Institute Symposium, and reviews.

The name of the Journal 'Conversazione' is attributable to the 'Tuesday Conversazione' at the Department of Electrical Engineering, which had been held once a week on Tuesday since around 1920. Minutes of the meetings had been distributed to researchers outside of the University via various routes and therefore some of them had been referred to as 'Records of Tuesday Electrical Engineering Conversazione Tohoku University' with the result that they came to be treated as official publications.

Though the meeting was once interrupted by World War Two, it was restarted in 1947. In 1952, the publication of the records was succeeded by the Institute and the records have been published as periodicals, two or three times a year recently, since No. 1 Vol. 21 was published in July, 1952.

2. The Annual Report of Research Activity at the Research Institute of Electrical Communication, Tohoku University

Published annually since 1995. This report details the activities of each research division and research facility. Also included are reports on nation-wide co-operative research projects, international symposium and seminars organized by members of RIEC, and the reports and evaluation on the RIEC advisory board members. English edition(digest version of Japanese edition) has been published since 2007.

3. RIEC News

As a part of RIEC's publication service, "RIEC News" is published.

With the 75th anniversary of the establishment of RIEC, RIEC News introduces cutting-edge's

research and the vision of the future from RIEC's contributions to the progression of science and technology in Japan. RIEC News was first launched in March 2011, In fiscal year 2014, 8th, 9th and 10th issues were published. Every issue introduces special topics such as large scale projects and Specially-Promoted Research, etc. RIEC News also includes current information about each laboratory and center, all kinds of RIEC events, research exchange meetings, laboratories open to the public (RIEC Open Day), etc. English version is also published in March 2014. Further, RIEC News offers a notification service by mail whenever a new issue is released and an electronic version of every issue published so far can be downloaded by following the link below.

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

9. Staff, Budget

1.Faculty & Staff

	as of May 1, 2014
Professors	24
Associate Professors	18
Assistant Professors	25
Research Fellows	14
Specially Appointed Professors	3
Administrative Staff	18
Technical Staff	11
Total	113

2.Researchers (FY2014)

Foreign Researchers	Visiting Professors	6
	Visiting Associate Professors	2
Cooperative Researchers of Private Company etc		5
JSPS Postdoctoral Fellows		7
Contract Researchers		5
Contract Trainees		1
Total		26

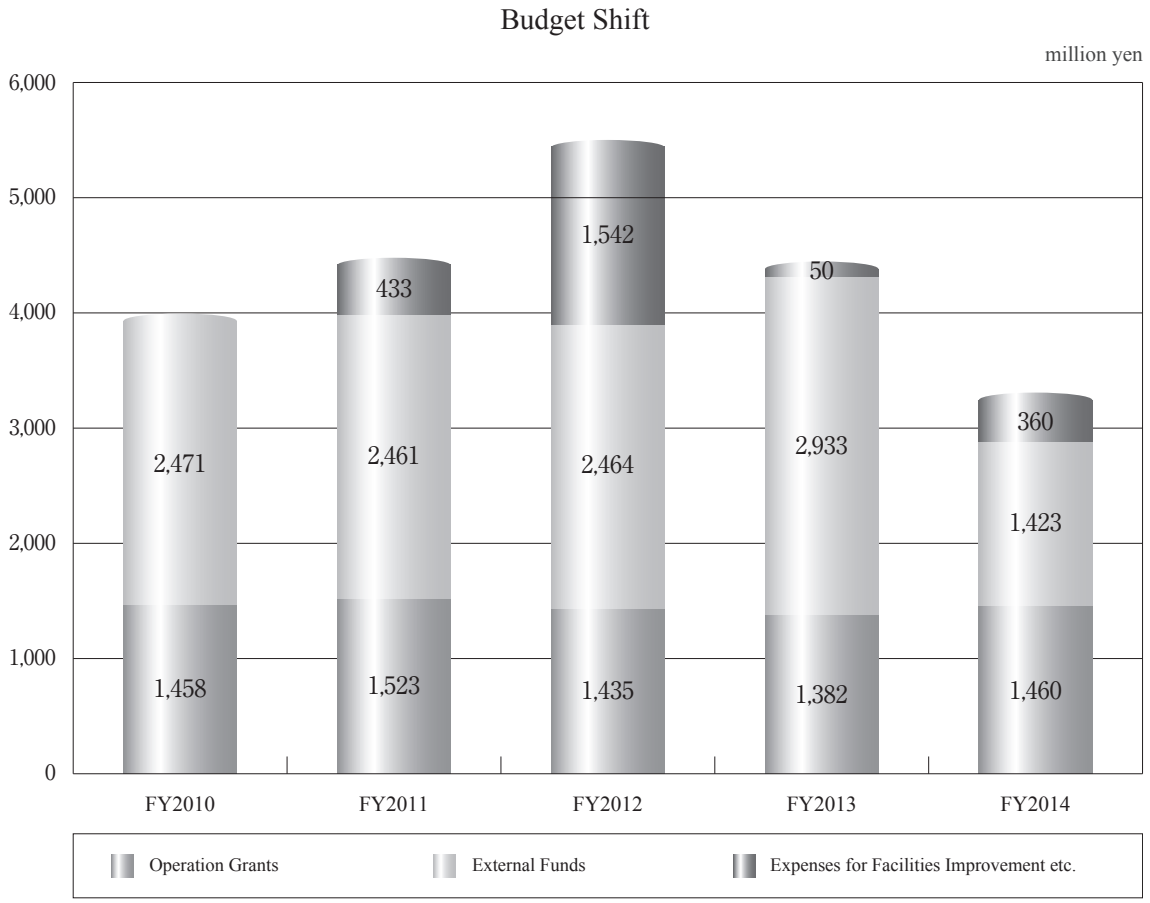
3.Students

as of May 1, 2014

	School of Engineering	Graduate School of Information Science	Graduate School of Biomedical Engineering	RIEC	Total
Undergraduate Students	56				56
Master Course Students	78 (6)	43 (6)	4		125 (12)
Doctor Course Students	30 (6)	8 (3)			38 (9)
Research Students				6 (5)	6 (5)
Total	164 (12)	51 (9)	4	6 (5)	225 (26)

※( ) Foreigner

5.Budget

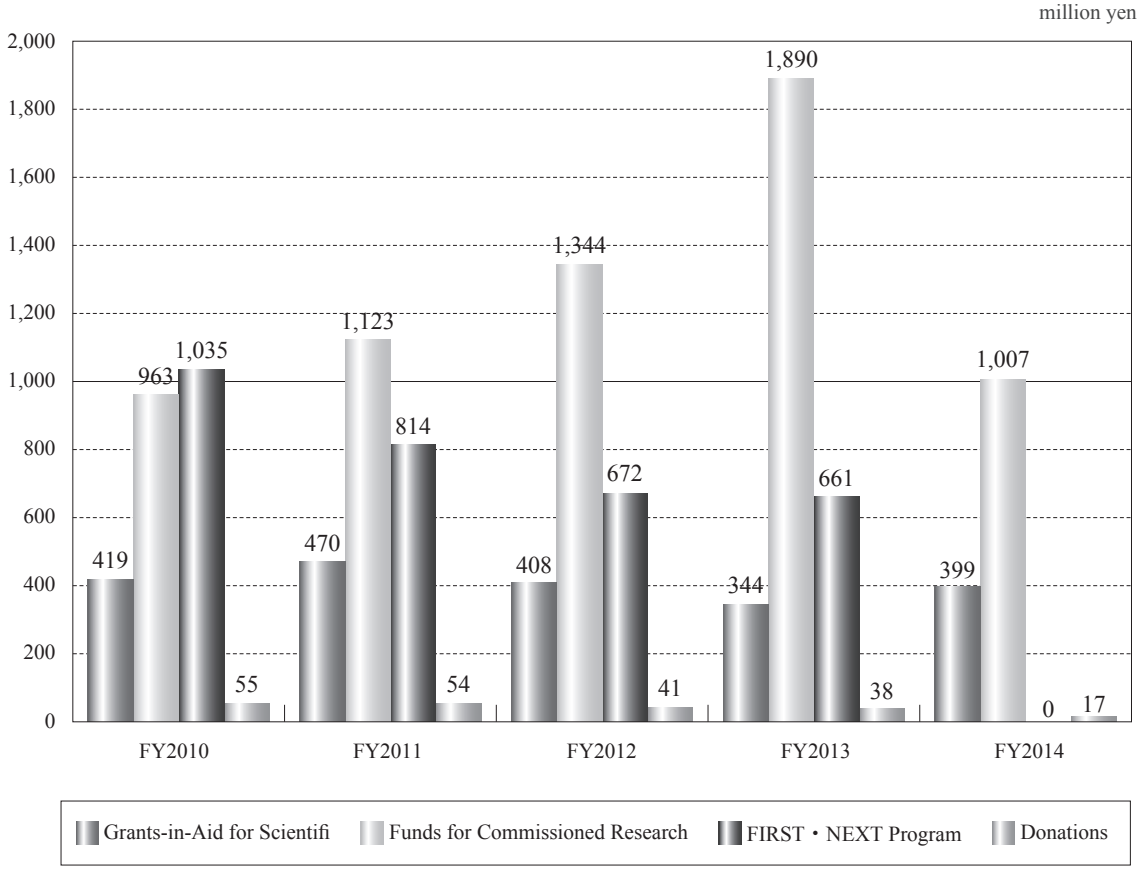


Budget Summary thousand yen

Categories		FY2010	FY2011	FY2012	FY2013	FY2014
Operation Grants	Personnel Expenses	777,776	835,898	770,443	723,507	791,174
	Non-Personnel Expenses	680,411	687,253	665,038	658,590	668,941
Operation Grants Total		1,458,187	1,523,151	1,435,481	1,382,097	1,460,115
External Funds	Grants-in-Aid for Scientific Research	418,680	469,840	407,629	343,824	399,311
	Funds for Commissioned Research	962,712	1,122,944	1,344,071	1,890,012	1,007,060
	FIRST Program ※1 • NEXT Program ※2	1,034,827	813,777	671,668	660,578	0
	Donations	55,085	54,167	40,714	38,100	16,890
	Indirect Expenses	275,547	311,801	326,869	336,037	212,669
External Funds Total		2,471,304	2,460,728	2,464,082	2,932,514	1,423,261
Expenses for Reconstruction			432,607	4,993	0	0
Expenses for Relocation		0	0	0	49,632	359,770
Expenses for Facilities Improvement		0	0	1,536,530	0	0
Expenses for Facilities Improvement etc. Total		0	432,607	1,541,523	49,632	359,770
Total		3,929,491	4,416,486	5,441,086	4,364,243	3,243,146

※1 FIRST Program…Funding Program for World-Leading Innovative R&D on Science and Technology (JSPS)
※2 NEXT Program…Funding Program for Next Generation World-Leading Researchers (JSPS)

External Funds



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thousand yen

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Annual Report 2014

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