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Annual Report 2012

Research Institute of Electrical Communication Tohoku University

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Annual report of Research Institute of Electrical Communication 2012

Contents

1. Introduction

This report summarizes the research carried out at RIEC during the 2012 fiscal year.

The RIEC was established in 1935 to research cutting-edge technologies such as Yagi-Uda antennas and magnetrons. Since then, it has made a succession of pioneering achievements in laying the foundations of information communication technology, and has continued to play a world-leading role. To build on this tradition, we are gearing our research towards the development and evolution of science and technology that will allow communications to be implemented in a way that enriches people's lives.

Since 2004, as a framework for this purpose, we have organized ourselves into four Research Divisions (Information Devices, Broadband Engineering, Human Iinformation Systems and Systems & Software), two Laboratories (Laboratory for Nanoelectronics and Spintronics and Laboratory for Brainware Systems), and one Research Center (Research Center for 21st Century Information Technology). Each entity has in mind the period of research to reach major outcome (Research Divisions: 20 years, Laboratories: 10 years, Research Center: 5 years). We have adopted a system of working in close cooperation with Tohoku University's graduate schools related 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 bridge people in a fundamentally different way.

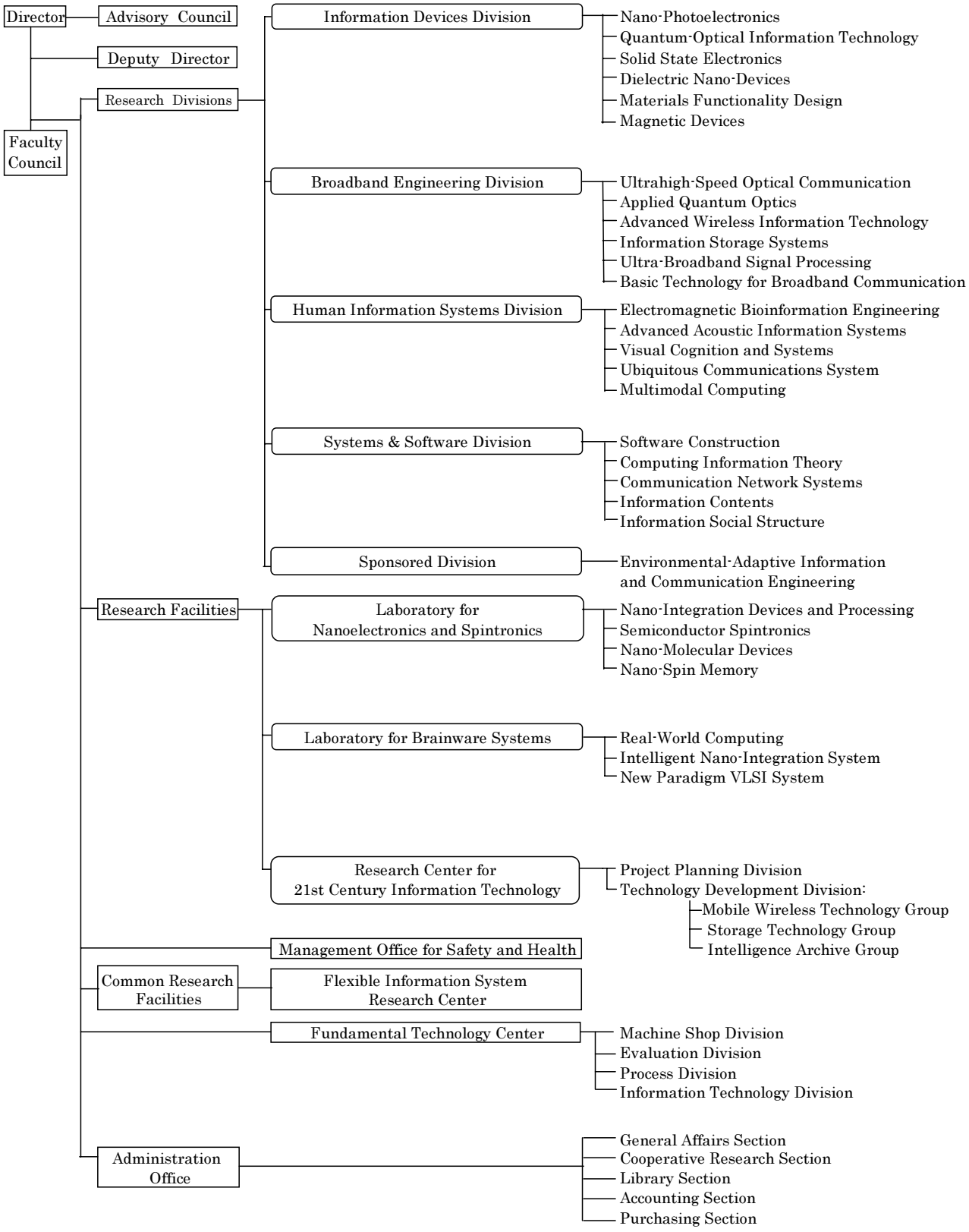
At the RIEC, we will continue to address these social needs by taking full advantage of our status as a university-affiliated research center. In this way, we hope to play a leading role in the new world of information science and technology, and thereby promote education in the future. We welcome your frank opinions regarding our research activities, and I sincerely hope we can continue to rely on your guidance and support in the future.

May 1, 2013

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 2012 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. In this year, we successfully measured STM light emission spectra with ps–temporal and nm–spatial resolution. We found that time resolved STM light emission spectra of Sb_2Te_3 show drastically changes for a few ps variation of optical delay between pump and probe laser pulses by which the tip-sample gap of STM is illuminated. STM light emission in the THz spectral region was successfully detected in the framework that has been theoretically investigated over last few years. It was already found that STM light emission spectra of Ag nanoparticles on solid surfaces contain information on vibrational energies of the substrates. In this year, Ag nanoparticles were successfully dropped at intended locations on the Si(111)-(7x7) surface by applying voltage pulses between the tip–sample gap of STM, and STM light emission from the Ag nanoparticles were observed. Carbon nanotubes (CNT) are a promised candidate for starting material of next generation optoelectronic nano–devices. A dry contact method for fixing individual CNT on solid substrates was improved so that the density of CNT fixed on the substrate for a once contact procedure was drastically increased, i.e., the attainable density becomes 20 times larger than those previously reported.

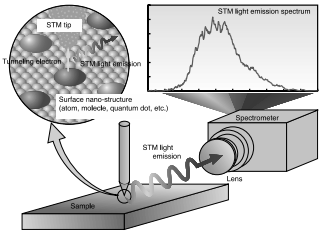


Fig. 1 STM light emission spectroscopy

[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] S. Katano, and Y. Uehara, "Light Emission from Single-walled Carbon Nanotube on Au(111) induced by Scanning Tunneling Microscope", The 29th European Conference on Surface Science (ECOSS-29), Edinburgh International Conference Center, Edinburgh, UK, 4 September (2012).

[2] S. Katano, Y. Kim, M. Trenary, and M. Kawai, "Orbital-selective Single Molecule Reactions on a Metal Surface Studied by Low-temperature Scanning Tunneling Microscopy", Chem. Commun., **49,** 4679-4681 (2013).

[3] K. Motobayashi, S. Katano, Y. Kim, and M. Kawai, "Spectral Fitting of Action Spectra for Motions and Reactions of Single Molecules on Metal Surfaces", Bull. Chem. Soc. Jpn., **86**, 75-79 (2013).

Quantum-Optical Information Technology

Development of optoelectronic devices for quantum information and communication technology

Quantum-Optical Information Technology: Keiichi Edamatsu, Professor
Quantum Solid State Physics: Hideo Kosaka, Associate 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 2012, we have achieved (1) experimental generation and activation of bound entanglement, (2) process tomography of quantum media conversion from photons to electron spins, and (3) observation of local-field effects on optical coherent transients of semiconductor quantum dots.

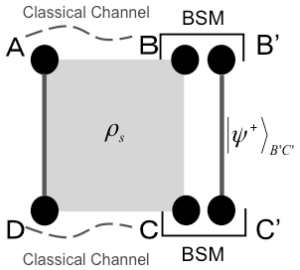


Fig. 1 Experimental generation and activation of bound entanglement.

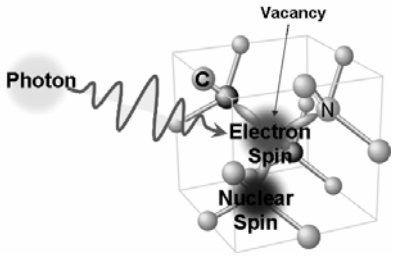


Fig. 2 Quantum media conversion from a photon to an electron/nuclear spin.

[Staff]

Professor: Keiichi Edamatsu, Dr.
Associate Professor: Hideo Kosaka,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.

Hideo Kosaka received B.S., M.S degrees in Physics from Kyoto University, and PhD degree in Electrical Engineering from Kyoto University. He was a Principal Researcher in NEC Opto-electronics and Basic Research Labs, a Visiting Associate in California University of Los Angeles.

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] H. Kosaka, T. Inagaki, R. Hitomi, F. Izawa, Y. Rikitake, H. Imamura, Y. Mitsumori, and K. Edamatsu, "Coherent transfer of time-bin photons to electron spins in a semiconductor," Phys. Rev. A **85**, 042304/1-8 (2012)

[2] M. Yabuno, R. Shimizu, Y. Mitsumori, H. Kosaka, and K. Edamatsu, "Four-photon quantum interferometry at a telecom wavelength," Phys. Rev. A **86**, 010302/1-4 (2012)

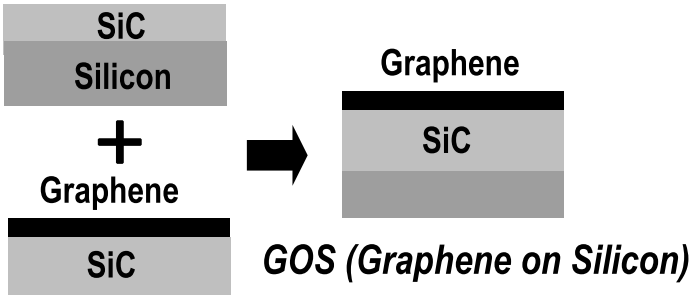
[3] F. Kaneda, R. Shimizu, S. Ishizaka, Y. Mitsumori, H. Kosaka, and K. Edamatsu, "Experimental activation of bound entanglement," Phys. Rev. Lett. **109**, 040501/1-5 (2012)

Solid State Electronics Laboratory

Paving a Way for Introducing Graphene into Silicon Technology

Solid State Electroncis　Maki Suemitsu, 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 FY2012, we developed GOS technology on micro-fabricated Si substrates, in which the graphene on the 3C-SiC(111) portion presents a Bernal stacking with interface buffer layer while that on (100) portion presents a metallic, non-Bernal graphene without the buffer layer. Understanding on the "rotated" epitaxy in which 3C-SiC(111) grows on Si(110) has also been enriched. By growing a thick 3C-SiC layer with this rotated epitaxy, we have enlarged the size of graphene by a factor of 1.6.

[Staff]

Professor：Maki Suemitsu, Dr.
Assistant Professor：Hirokazu Fukidome, Dr.
Research Assistant：Sai Jiao, Dr.
Technical Assistant：Akemi Miura

[Profile]

Prof. Maki Suemitsu obtained bachelor degree on electronic enginnering (1975), Ph.D on electronic engineering (1980). He started his service at Research Institute of Electrical Communication (RIEC) as research associate (1980), and became associate professor (1990). He then became professor at Center for Inderdisciplinary Research (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).

[Papers]

[1] Takayuki Ide, Yusuke Kawai, Hiroyuki Handa, Hirokazu Fukidome, Masato Kotsugi, Takuo Ohkochi, Yoshiharu Enta, Toyohiko Kinoshita, Akitaka Yoshigoe, Yuden Teraoka, and Maki Suemitsu, "Epitaxy of Graphene on 3C-SiC(111) Thin Films on Microfabricated Si(111) Substrates," Jpn. J. Appl. Phys. Vol.51, No. 6, pp. 06FD02-1-06FD02-4, 2012

[2] H. Fukidome, Y. Kawai, F. Fromm, M. Kotsugi, H. Handa, T. Ide, T. Ohkouchi, H. Miyashita, Y. Enta, T. Kinoshita, Th. Seyller, and M. Suemitsu "Precise control of epitaxy of graphene by microfabricating SiC substrate," Appl. Phys. Lett. Vol. 101, No.7, pp. 041605-1-041605-5, 2012

[3] Maki Suemitsu, Shota Sanbonsuge, Eiji Saito, Myung-Ho Jung, Hirokazu Fukidome, Sergey Filimonov, "High-rate rotated epitaxy of 3C-SiC(111) on Si(110) substrate for qualified epitaxial graphene on silicon," Mat. Sci. Forum Vol. 740-742, pp. 327-330, 2013

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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.

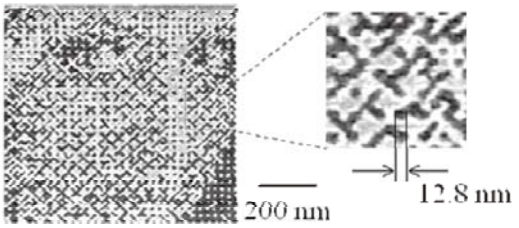

Fig.1 Digital bit data written on ferroelectric single crystal with the areal recording density of 4 Tbit/inch^2.

Major achievements of studies in 2012 are as follows: (1) The origin of the atomic contrast in the dipole moment imaging of Si(111)-(7×7) surface was studied based on simultaneous measurement of time-averaged tunneling current images. The results suggested the electric fields from atomic dipole moments cause the shift of surface potential, which locally enhances the asymmetry of current-voltage characteristics. (2) The lateral resolution in observation of ferroelectric domains was improved by using super-higher-order nonlinear dielectric microscopy. The more detailed structures of MOSFETs were also obtained using the same method. (3) Accumulated charges in MONOS-type flash memory were visualized with high resolution by detecting the higher-order (2-4 order) nonlinear permittivity.

[Staff]

Professor : Yasuo Cho, Dr.
Visiting Professor : Koichiro Honda, 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, K. Yamasue, Y. Hiranaga, K. Honda and Y. Cho, "Lateral resolution improvement in scanning nonlinear dielectric microscopy by measuring super-higher-order nonlinear dielectric constants", Appl. Phys. Lett., Vol. 101, (2012) pp.213112-1-213112-4.

[2] K. Honda and Y. Cho, "Scanning nonlinear dielectric microscopy observation of accumulated charges in metal-SiO_2-SiN-SiO_2-Si flash memory by detecting higher-order nonlinear permittivity", Appl. Phys. Lett.,Vol. 101, (2012) pp.242101-1 -242101-5.

[3] K. Yamasue and Y. Cho, "Simultaneous measurement of tunneling current and atomic dipole moment on Si(111)-(7×7) surface by noncontact scanning nonlinear dielectric microscopy", J. Appl. Phys., Vol. 113 (2013) pp.014307-1-014307-8.

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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 2012 are as follows:

(1) Transport in spinel-barrier magnetic tunnel junctions

We investigated the transport properties of Fe/$MgAl_2O_4$/Fe junctions using first-principles calculations. Since the in-plane cell size of $MgAl_2O_4$ is twice that of MgO, a new Δ_1 conductive channel appears in the minority-spin state due to folding of Fe conduction bands. The tunnelling magneto-resistance (TMR) ratio of Fe/$MgAl_2O_4$/Fe is an order of magnitude smaller than that of Fe/MgO/Fe [1]. A cation-site disorder in $MgAl_2O_4$ suppresses the band folding and thus enhances the TMR ratio, since the disorder hardly affects the majority-spin coherent tunneling via oxygen orbitals in $MgAl_2O_4$ (Fig. 1) [2].

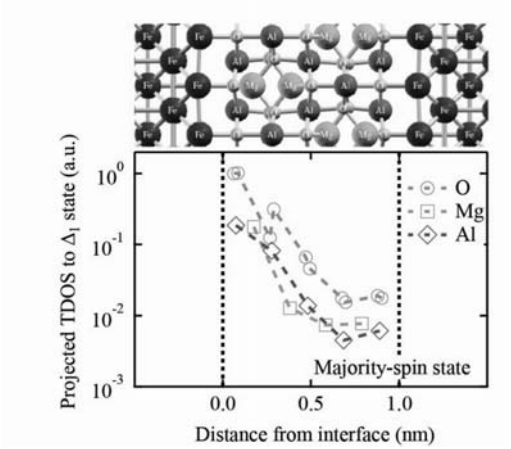

Fig. 1

(2) Magneto-crystalline anisotropy in an ordered FeNi alloy

We investigated the origin of magneto-crystalline anisotropy (MCA) in $L1_0$-ordered FeNi alloy using first-principles calculations. The uniaxial MCA of FeNi arises predominantly from the constituent Fe atoms, since the Fe orbital magnetic moment depends remarkably on the magnetization direction. Further enhancement of the MCA is expected by reducing the in-plane lattice parameter of FeNi [3].

[Staff]

Professor : Masafumi Shirai, Dr.
Assistant Professor : Yoshio Miura, Dr.
Assistant Professor : Kazutaka Abe, Dr.
Research Fellow: Masahito Tsujikawa, Dr.

[Profile]

Masafumi Shirai was received the Doctor of Engineering degree from Osaka University in 1989. From 1988 to 1996, he was a Research Associate, and then 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 and device structures in spintronics.

[Papers]

[1] Y. Miura, S. Muramoto, K. Abe and M. Shirai, "First-principles study of tunneling magnetoresistance in Fe/$MgAl_2O_4$/Fe (001) magnetic tunnel junctions," Phys. Rev. B, Vol. 86, No. 2, Article No. 024426, pp. 1-6, 2012

[2] H. Sukegawa, Y. Miura, S. Muramoto, S. Mitani, T. Niizeki, T. Ohkubo, K. Abe, M. Shirai, K. Inomata and K. Hono, "Enhanced tunnel magnetoresistance in a spinel oxide barrier with cation site disorder," Phys. Rev. B, Vol. 86, No. 18, Article No. 184401, pp. 1-5, 2012

[3] Y. Miura, S. Ozaki, Y. Kuwahara, M. Tsujikawa, K. Abe and M. Shirai, "Origin of perpendicular magneto- crystalline anisotropy in $L1_0$-FeNi under tetragonal distortion," J. Phys.: Condens. Matter, Vol. 25, No. 10, Article No. 106005, pp. 1-9, 2013

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3.2 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, storage, and semiconductor spintronics technologies.

(1) Advanced Wireless Information Technology

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. We are also working for the next generation wireless communication systems/devices which include a location & short message communication system via Quasi-Zenith Satellite System (QZSS) and a fusion of various wireless communication systems "Dependable Air."

(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 have theoretically discovered giant gain enhancement of surface plasmon polaritons in THz range in population-inverted graphene, monolayer of carbon atomic honeycomb crystal, by whose extraordinary carrier transport properties we proposed a novel THz lasers and experimentally verified stimulated THz emission at room temperature. Second, we devised novel plasmon-resonant THz emitter/detector devices, succeeding in world-first coherent monochromatic THz plasmonic lasing and breaking the record sensitivity to 22.7 kV/W and 6.4 kV/W at 220-GHz and 1.5-THz radiation, respectively.

(3) Ultrahigh-Speed Optical Communication

To achieve a global high-capacity optical network, we have been engaged 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 successfully demonstrated 1024 QAM coherent optical transmission for the first time, and achieved an ultrahigh spectral efficiency of more than 13 bit/s/Hz.

We also proposed a novel optical pulse called optical Nyquist pulse, and demonstrated 160~640 Gbaud transmission over 500 km with substantial improvement in tolerance to chromatic dispersion and polarization-mode dispersion.

(4) Applied Quantum Optics

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

Ultra-high-speed semiconductor photonic active devices are being investigated. The study on high-speed operation of external cavity semiconductor lasers by injecting high-speed signal light is being continued. It is confirmed that the 3 dB bandwidth of the laser is enlarged to more than 40 GHz by measuring the frequency response of the fabricated device. The study on multi-carrier generation by using a semiconductor Mach-Zehnder modulator is also being proceeded. Nine-channel sidebands (optical frequency comb) generation with very low power deviation of less than 1 dB is confirmed by operating the modulator under asymmetric differential drive condition.

(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 unveiled that areal density of 5 Tbit/inch^2, which is tenfold of current density, was difficult only by the bit-patterned media by theoretical approach with a computer simulation. For such high density, we clarified thermal assist recording technique that heats a narrow recording area is indispensable. Storage system technology to enhance the data transfer rate was also developed.

(6) Basic Technology for Broadband Communication (Inutake Lab.)

Synthetic aperture radars (SAR) are useful for all-weather surveillance and rescue. We have developed an air-borne SAR under the research contract of 2009-2012, with Ministry of Land, Infrastructure, Transport and Tourism (MLIT). In this fiscal year, a real-time imaging radar “Live SAR” with a high resolution (10 cm), small size and light weight (25 kg) at Ku-band has been completed and successfully tested on board of a helicopter “Fuji-Bell 405”. Scientists and engineers of universities and industries collaborated to carry out this program.

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 generation and transmission. This year, we successfully achieved 1024 QAM coherent optical transmission, highly dispersion and PMD-tolerant 160~640 Gbaud optical Nyquist pulse transmission, and 1.6 Tbit/s coherent RZ-32 QAM transmission. Figure 1 shows the result of 3 Gsymbol/s, 1024 QAM transmission over 150 km. 60 Gbit/s data were transmitted within a bandwidth of only 4.05 GHz, resulting in a spectral efficiency as high as 14.8 bit/s/Hz.

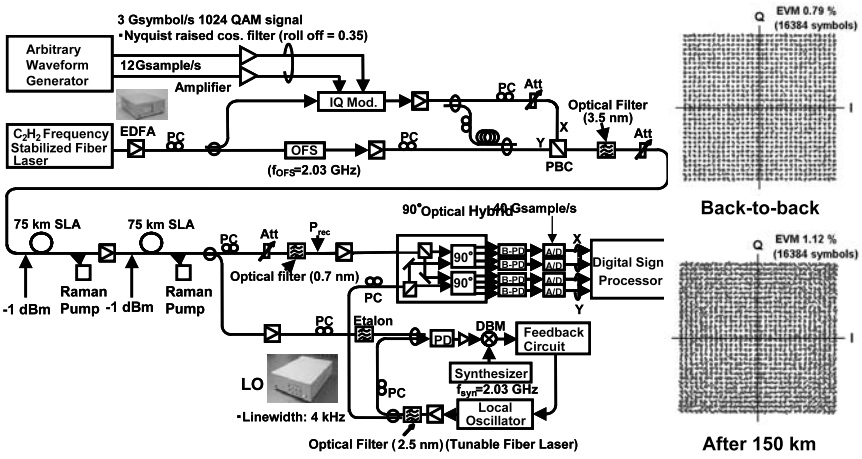

Fig. 1 1024 QAM (60 Gbit/s) coherent optical transmission.

[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 and International Advanced Research and Education Organization.

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] Y. Koizumi, K. Toyoda, M. Yoshida, and M. Nakazawa, "1024 QAM (60 Gbit/s) single-carrier coherent optical transmission over 150 km," Opt. Express, vol. 20, no. 11, pp. 12508-12514, May (2012).
[2] M. Nakazawa, M. Yoshida, and T. Hirooka, "Nondestructive measurement of mode couplings along a multi-core fiber using a synchronous multi-channel OTDR," Opt. Express, vol. 20, no. 11, pp. 12530-12540, May (2012).
[3] T. Hirooka, P. Ruan, P. Guan, and M. Nakazawa, "Highly dispersion-tolerant 160 Gbaud optical Nyquist pulse TDM transmission over 525 km," Opt. Express, vol. 20, no. 14, pp. 15001-15008, July (2012).

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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 photonic integrated circuits are being investigated to explore new-generation photonic network systems.

Ultra-high-speed semiconductor photonic active devices are being investigated. The study on high-speed operation of passive feedback semiconductor lasers (PFLs) by injecting high-speed signal light is being continued. It is confirmed that the 3 dB bandwidth of the PFL is enlarged to more than 40 GHz by measuring the frequency response of the fabricated device.

The study on highly functional semiconductor optical modulators is also being proceeded. Multi-carrier generation by using a semiconductor Mach-Zehnder modulator is carried out to realize compact multi-wavelength light sources (optical comb block generators). By applying sinusoidal RF signal to the modulator in a push-pull manner, optical frequency comb block with 9 channel sidebands can be generated with a power deviation of less than 5 dB. Wavelength dependence of modulator's half-wavelength voltage (V_π) becomes a problem when the semiconductor Mach-Zehnder modulator is used in wide wavelength range. By adjusting the DC bias voltage applied to the modulator, the same comb spectra can be generated in wide wavelength range from 1525 to 1560 nm. Very low power deviation of less than 1 dB is also confirmed by operating the modulator under asymmetric differential drive condition.

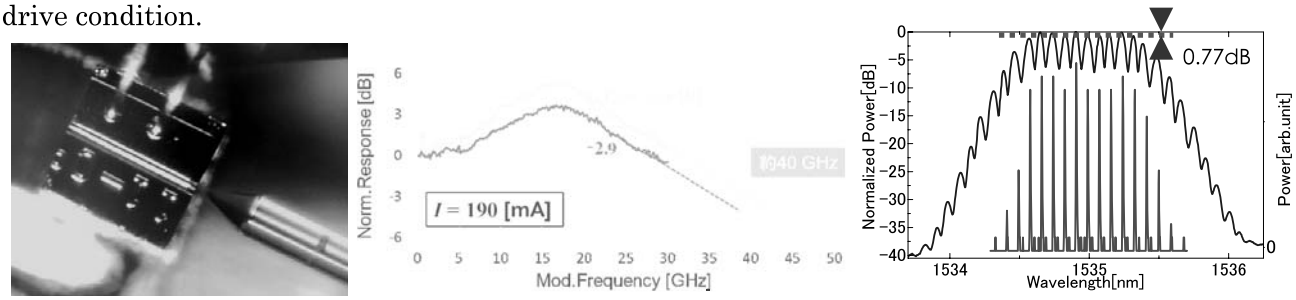

Photo of functional semiconductor photonic device (left), measured frequency response of PFL under signal light injection condition (middle), and a generated optical frequency comb block by using a semiconductor Mach-Zehnder modulator (right).

[Staff]

Professor : Hiroshi Yasaka, 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] H. Yasaka and Y. Shibata, “Fiber Optic Communication - Key Devices,” Chapter 6, “Semiconductor-based Modulators,” ISBN 978-3-642-20516-3, pp. 227-280, Springer-Verlag (Berlin, Heidelberg), 2012.

[2] H. Ishihara, Y. Saito, W. Kobayashi, and H. Yasaka, "Bandwidth enhanced operation of single mode semiconductor laser by intensity modulated signal light injection," IEICE Transactions on Electronics, vol. E95-C, No. 9, pp. 1549-1551, 2012.

[3] T. Yamamoto, K. Hitomi, W. Kobayashi, and H. Yasaka, “Optical Frequency Comb Block Generation by using Semiconductor Mach-Zehnder Modulator,” IEEE Photonics Technology Letters, vol. 25, No. 1, pp. 40-42, 2013.

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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.

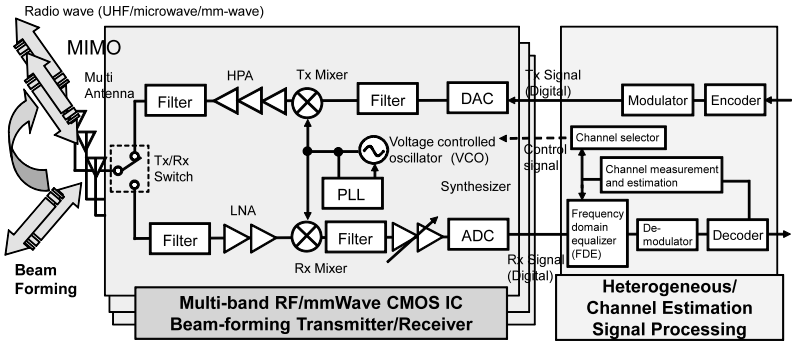

Fig. The target system of
Advanced Wireless Information Technology Laboratory.

For the studies on signal processing, RF/Mixed signal device and antenna technologies, we are developing millimeter wave RF CMOS IC's, antenna integrated 3-dimensional system in package (SiP) transceiver modules and, digital/RF mixed signal IC's.

As for the studies on MODEM and network technologies, we are focusing on next generation mobile broadband wireless access (MBWA: mobile broadband wireless access), dependable broadband wireless local area network (WLAN) and ultra-broadband wireless personal area network (WPAN).

[Staff]

Professor: Noriharu Suematsu, Ph. D
Associate Professor: Suguru Kameda, Ph. D
Research Fellow: Shoichi Tanifuji, Ph. D

[Profile]

Noriharu Suematsu received the M.S. and Dr. 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, 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 Research Institute of Electrical Communication. From 2012, he has been currently an associate professor.

[Papers]

[1] S. Kameda et al., "Proposal of Heterogeneous Wireless Network with Handover in Application Layer: Feasibility Study Based on Field Trial Results," IEICE Trans. Commun., vol.E95-B, no.4, pp.1152-1160, April 2012.
[2] N. Suematsu et al., "A 60 GHz-Band 3-Dimensional System-in-Package Transmitter Module with Integrated Antenna," IEICE Trans. Electron., vol.E95-C, no.7, pp.1141-1146, July 2012 (invited).
[3] S. Yoshida et al., "60-GHz Band Copper Ball Vertical Interconnection for MMW 3-D System-in-Package Front-End Modules," IEICE Trans. Electron., vol.E95-C, no.7, pp.1276-1284, July 2012.

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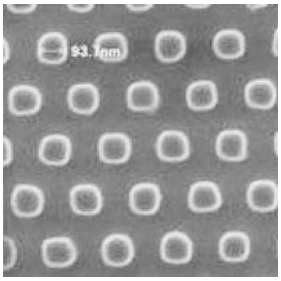
Information Storage System

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 exceed 1000 Exa-byte in 2010. 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.

In addition to the studies on magnetic recording, research on information storage systems (Fig. 2) is being carried out. Perpendicular recording technology for 5 Tbits/inch2 areal recording density is investigated, which reduces the number of HDDs by 1/10, and low power architecture of tiered RAID system.

[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] S.J. Greaves, H. Muraoka, Y. Kanai, "The potential of bit patterned media in shingled recording," J. Magn. Magn. Mater., 324, 3, pp. 314-320, 2012.
[2] Kenji Miura, Hiroyuki Katada, Makoto Oguma,Yasutaka Nishida, and Hiroaki Muraoka, "Erase Band Noise and Generation Mechanism Due to an Adjacent Track," IEEE Trans. Magn. (in press)
[3] Simon John Greaves, Yasushi Kanai, and Hiroaki Muraoka, "Thermally assisted magnetic recording at 4 Tbit/in2," IEEE Trans. Magn., (in press)

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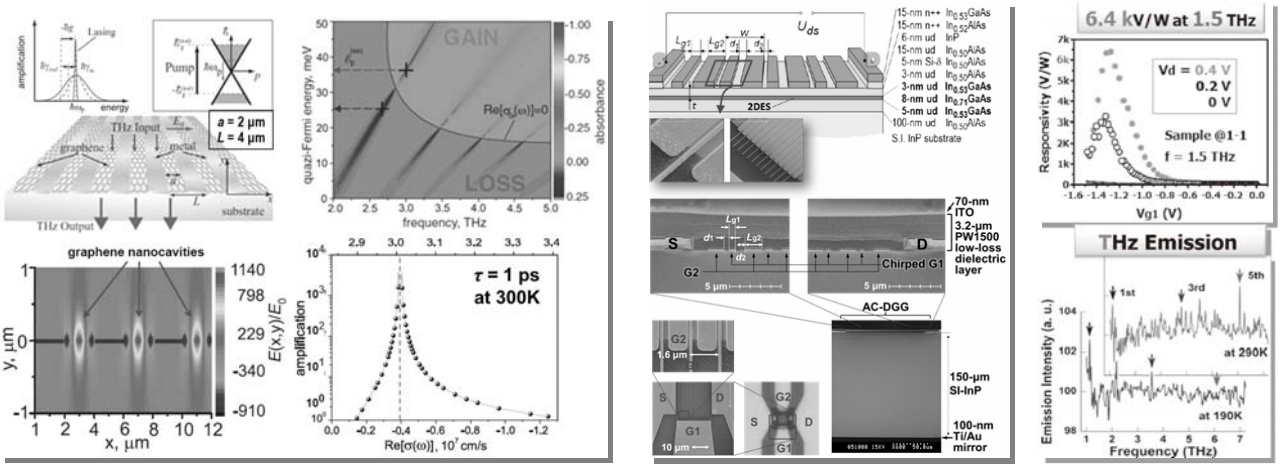
Ultra-broadband Signal Processing

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

[Research Target and Activities]



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

(Left: superradiant terahertz (THz) lasing with giant gain in population-inverted graphene-metal ribbon arrays, center: InP-based asymmetric dual-grating-gate (A-DGG) HEMT, right: record-breaking THz detection sensitivity (upper) and world-first coherent, monochromatic THz emission (lower) from the A-SGG HEMT.)

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.
Assistant Professor: Akira Satou, Dr. Comp. Sci.
Assistant Professor: Susumu Takabayashi, Dr. Eng.
Post-Doctoral Research Fellow: Adrian Dobroiu, Ph.D. 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. Member of IEEE(Senior), OSA (Senior), 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.

[Papers]

[1] T. Otsuji, *et al.*, IEEE Trans. Terhrz. Sci. Tech., Vol. 3, No. 1, pp. 63-72, 2013.
[2] T. Watanabe, *et al.*, IEEE Sensors J., Vol. 13, No. 1, pp. 89-99, 2013.
[3] T. Otsuji, *et al.*, MRS Bulletin, Vol. 37, No. 12, pp. 1235-1243, 2012.
[4] V.V. Popov, *et al.*, Phys. Rev. B, Vol. 86, Iss. 19, pp. 195437-1-6, 2012.

INUTAKE Laboratory

High Resolution Synthetic Aperture Radar for Civilian Applications

Fig.1 “Live SAR” boarded on Fuji-Bell 405 helicopter

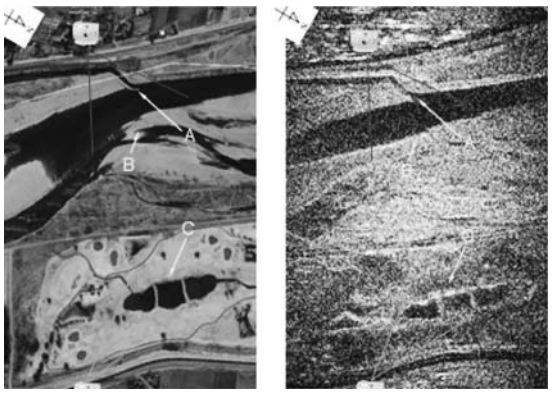


Fig.2 (left) Google map, (right) “Live SAR” image of Kinugawa-river and golf-course.

Basic Technology for Broadband Communication : Masaaki Inutake, Professor

[Research Target and Activities]

We have developed an air-borne synthetic aperture radar (SAR) for civilian applications. The SAR is useful for all-weather surveillance and rescue in large-scale natural disasters. Scientists and engineers from both universities and industries collaborated on this research project. Under the research contract with Ministry of Land, Infrastructure, Transport and Tourism (MLIT), a real-time imaging radar “Live SAR” , as shown inFig.1 was successfully completed in 2010, with a high resolution (10 cm), small size and light weight (25kg) at Ku-band, and in 2011, softwares for image formation and user interface for “Live SAR” has been developed, and in 2012, images have been successfully gotten, as shown inFig.2 by use of “Live SAR” boarded on “Fuji-Bell 405” helicopter (Fig.1).

[Staff]

Visiting Professor : Masaaki Inutake, Dr.

[Profile]

1966: Bachelor of Engineering, University of Tokyo.
1972: Doctor of Engineering, University of Tokyo.
1972-1974: Research Fellow, Institute of Space and Aeronautical Science, University of Tokyo.
1974-1980: Assistant Professor, Institute of Plasma Physics, Nagoya University
1980-1994: Associate Professor, Graduate School of Applied Physics, University of Tsukuba.
1994-2007: Professor, Graduate School of Engineering, Tohoku University.
2007-present: Visiting Professor, Research Institute of Electrical Communication, Tohoku University.
Researches: Alfven wave physics and its applications to the wave heating of a fusion plasma and the acceleration of supersonic plasma flows in a magnetic nozzle for an advanced space propulsion. Prizes for Science & Technology (Research Category), Commendation for Science & Technology by the Minister of Education, Culture, Sports, Science and Technology, (April, 2008).

[Papers]

[1] M. Inutake, M. Yamashika, et al., Exhibition of “Live SAR”, Japan Int’l Aerospace Exhibition 2012, Port-messe Nagoya / Chubu Int’l Airport, 9-14 Oct. (2012).
[2] Y. Kogi, H. Ikezi, A. Mase, M. Inutake, M. Sato, “Split-beam SAR”, Patent No. 5035782, granted on 13 July (2012)
[3] M. Inutake, H. Ikezi, A. Mase, Y. Kogi, M. Sato, “Laser Radar and Laser SAR devices”, Japanese unexamined patent application publication No. 2012-154863, 16 Aug. (2012).

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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 2012 of each laboratory are described in detail below.

(1) Electomagnetic Bioinformation Engineering

(Aims) This laboratory aims at obtaining the high accuracy sensor system for the signals from the human body or electric devices and at obtaining the system for approaching action to the human body by using the nano-scale controlled magnetic materials and by the development of the devices under the functions of the magnetics.

(Achievements)

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.

(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 FY2012, 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, such as 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, 252-ch 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 the low-level motion mechanisms for color and luminance and their integration process using 2D and 3D motion aftereffects (MAEs). We found that the visual system has the low-level motion mechanism for color motion as well as for luminance motion. Secondly, we investigated the transfer of the contextual cueing effect to images from a different viewpoint by using visual search displays of 3D objects. For images from a different viewpoint, the contextual cueing effect was maintained with self-motion but disappeared when the display changed without self-motion. This suggests that the spatial representation of object layouts can be obtained and updated implicitly. Thirdly, we investigated the neural representation and the flow of visual information in human visual cortex, especially in relation to color.

(4) Ubiquitous Communications System

(Aims) The goal of ubiquitous communications is to realize communications environments in that everybody can communicate with anybody, anywhere and anytime without recognizing the communications tools. Towards this goal, the core technologies to realize Super Broad Band Indoor Wireless Communications have been in research and development with which people can enjoy multiple Gbps transmission freely. In addition, a wide area sensor network that also can work as a disaster relief network in the case of emergency has been in research and development.

(Achievements) Our major achievements in this year include (i) development of commercially applicable 60 GHz odd-numbered-elements beam-forming antennas for portable terminals, (ii) 60 GHz indoor propagation channel model creation for the systems deploying reflected waves and a beam tracking receive antenna (iii) Improvement of indoor communications interruption probability by the factor of 10, all leading to real Super Broad Band Indoor Wireless Communications deployment, (iv) a wide area sensor network proposal and contributions to IEEE Standardization aiming at standardization completion in FY2013 in addition to basic transmitter and receiver design, synchronization design and interference

resistance analysis, all needed for whole wireless sensor network design and co-existence with other systems in ISM bands.

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.

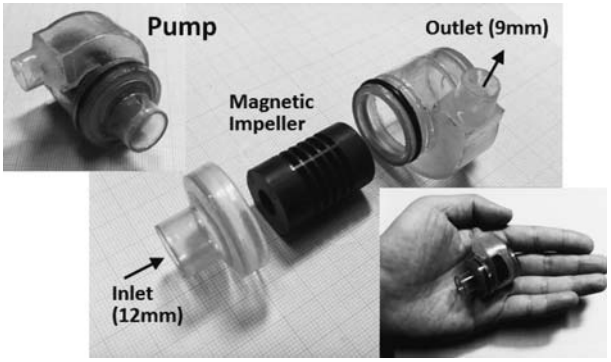

Fig. 1 Prototype of wireless artificial heart assist blood pump

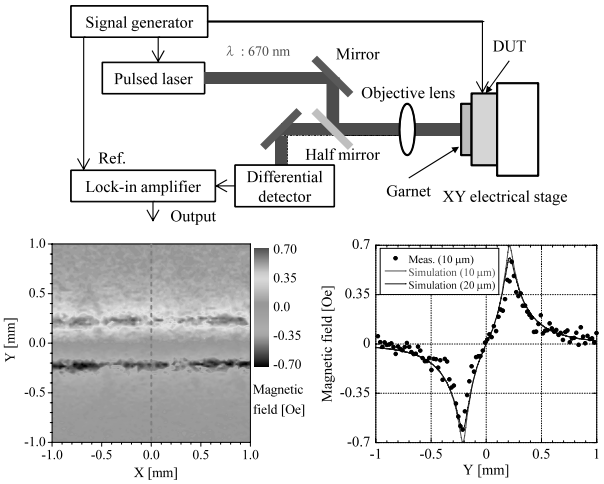

Fig. 2 High frequency magnetic field imaging system using magneto-optical crystal probe

[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] Y. Hayashi, S. Hashi, K. Ishiyama, "Magnetic Properties of Nanostructured Film Composed of Co-ferrite Nanoparticles and Metal Co Prepared by Combination of Electrophoretic Deposition and Electroplating," IEEE Trans. Magn., Vol. 48, pp. 3170-3173, (2012).

[2] S. H. Kim, S. Hashi, and K. Ishiyama, "Actuation of Novel Blood Pump by Direct Application of Rotating Magnetic Field," IEEE Trans. Magn., Vol. 48, pp. 1869-1874 (2012).

[3] J. W. Shin, S. H. Kim, Y. Suwa, S. Hashi, K. Ishiyama, "Control of in-plane uniaxial anisotropy of $Fe_{72}Si_{14}B_{14}$ magnetostrictive thin film using a thermal expansion coefficient," J. Appl. Phys., Vol. 111, No. 7, pp. 07E511-1-3, (2012).

[4] S. H. Kim, J. W. Shin, S. Hashi, K. Ishiyama, M. Ozaki, S. Matsumura, "Fabrication of a fully magnetic impeller for improvement of the magnetic properties of a pump with a power harvester," J. Appl. Phys., Vol. 111, No. 7, pp. 07E705-1-3, (2012).

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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 a study of the information processing in the human auditory system. We are, at the same time, aiming at the realization of a 'comfortable' sound environment exploiting digital signal processing techniques. Three-dimensional auditory displays based on the sound image control by simulating transfer functions of sound paths from sound sources to listeners' external ears, and sensing systems of 3D sound field information are two examples. These systems are expected to provide a high-quality virtual sound space, which is keenly required to realize in the multimedia communications, cyberspace systems and visual reality systems. Moreover, in 2012, we put a lot of effort to develop a system to acquire 3D sound-space information that can save, transmit, and reproduce accurate sound-space information to a distant place using a microphone array on a human-head-sized solid sphere with numerous microphones on its surface, and investigate how people perceive sound-space information while their heads are rotating.

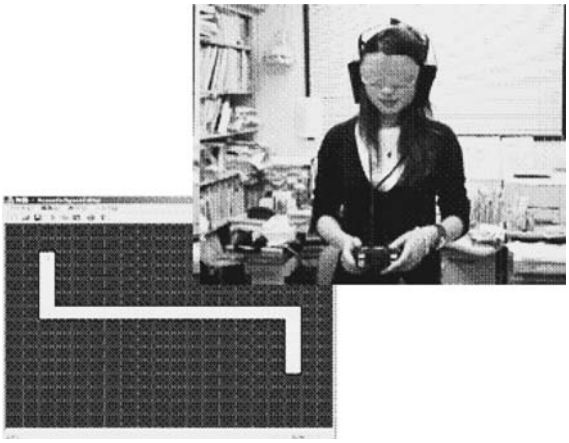

Fig. 1 Application for training spatial cognition based on high-definition virtual auditory display

[Staff]

Professor: Yôiti Suzuki, Dr.
Associate Professor: Shuichi Sakamoto, Dr.
Visiting Professor: Masayuki Morimoto, Dr.
Technical Official: Fumitaka Saito, Research Fellow: Zheng Lie Cui, Dr.

[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 a 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, S. Sakamoto, F. Furune, J. Gyoba and Y. Suzuki, "Compression of auditory space during forward self-motion," PLoS ONE, 7(6), e39402. (2012)
[2] J. Trevino, Y. Iwaya, Y. Suzuki, T. Okamoto, "Ambisonic synthesis of directional sources using non-spherical loudspeaker arrays," Proc. of 25th AES UK Conference (2012) 10 (5 pages in CD-ROM) (2012)
[3] Y. Suzuki, T. Okamoto, J. Trevino, Z-L Cui, Y. Iwaya, S. Sakamoto and M. Otani, "3D spatial sound systems compatible with human's active listening to realize rich high-level kansei information," Interdisciplinary Information Sciences Journal, 18(2), 71-82 (2012).

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]

Our target is to understand the vision-related brain functions in order to apply the knowledge to realize human oriented information communication systems. We made achievements in the fields of visual attention, depth perception and color perception.

Firstly, we investigated the low-level motion mechanisms for color and luminance and their integration process using 2D and 3D motion aftereffects (MAEs). We found that the visual system has the low-level motion mechanism for color motion as well as for luminance motion. Secondly, we investigated the transfer of the contextual cueing effect to images from a different viewpoint by using visual search displays of 3D objects. For images from a different viewpoint, the contextual cueing effect was maintained with self-motion but disappeared when the display changed without self-motion. This suggests that the spatial representation of object layouts can be obtained and updated implicitly. Thirdly, we investigated the neural representation and the flow of visual information in human visual cortex, especially in relation to color.

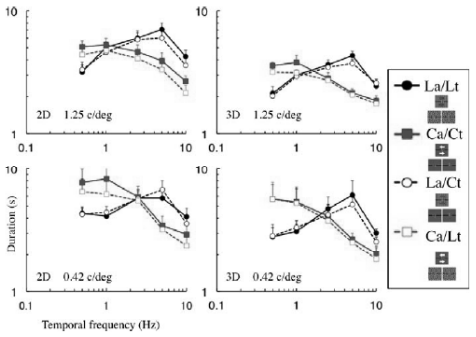

Figure. Duration of 2D (left) and 3D (right) MAEs as temporal frequency of motion stimulation in the adaptation phase for 1.25 (top) and 0.42 (bottom) c/deg gratings.

[Staff]

Professor : Satoshi Shioiri, Ph.D.
Associate Professor : Ichiro Kuriki, Ph.D.

[Profile]

Satoshi SHIOIRI Professor Shioiri graduated Tokyo Institute of Technology and received Dr. Eng in 1986. Then, he was a postdoctoral researcher at University of Montreal until May of 1989. From June of 1989 to April of 1990, he was a research fellow at Auditory and Visual Perception Laboratories of Advanced Telecommunications Research Institute. He moved to Chiba University at May of 1990, where he spent 15 years as an assistant professor, an associate professor, and a professor of Department of Image Sciences Department of Image, Information Sciences and Department of Medical Systems. In 2005, he moved to Tohoku University. Since then, he has been a professor of Research Institute of Electrical Communication of Tohoku University.

Ichiro KURIKI Dr. Kuriki received Ph.D. degree from Tokyo Institute of Technology in 1996. After then, he worked at Imaging Science and Engineering Laboratory, Tokyo Institute of Technology as a research associate until October, 1999. He worked as a research associate at the Department of Mathematical Engineering and Information Physics, Graduate School of Engineering, the University of Tokyo until March, 2001. He worked as a researcher in Communication Science Laboratories of NTT Corporation until December, 2005. He joined the Research Institute of Electrical Communication, Tohoku University as an Associate Professor in January, 2006.

[Papers]

1. Low-level motion analysis of color and luminance for perception of 2D and 3D motion. Journal of Vision Vol. 12, No. 6, Article 33, 1-14, 2012. Shioiri S, Yoshizawa, M, Ogiya M, Matsumiya K, Yaguchi H
2. Implicit learning of viewpoint-independent spatial layouts, *Frontiers in Psychology*, Vol. 3, 207 pp. 1-10, 2012, TaigaTsuchiai Kazumichi Matsumiya, Ichiro Kuriki and Satoshi Shioiri
3. Investigation of color constancy in 4.5-month-old infants under a strict control of luminance contrast for individual subjects. *Journal of Experimental Child Psychology*, 115, 126-136, 2013. Yang J, Kanazawa S, Yamaguchi MK, and Kuriki I.

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Ubiquitous Communications System

R&D on Super Broadband Wireless Communications & ISWAN

Ubiquitous Communications Systems: Shuzo Kato, Professor
Ubiquitous Communications Devices: Hiroyuki Nakase, Associate Professor

[Research Target and Activities]

Research Target: 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 Super Broadband Wireless Communications in which people can communicate at multi-Gbps freely.

FY2012 Major Results: (i) Odd-numbered beam forming antennas have been developed successfully to ease manufacturing antennas while keeping the required antenna performance. The developed 5-element beam-forming antenna is shown in Fig.1 and its antenna directivity in Fig.2. (ii) A new channel model has been established for the proposed 60 GHz systems deploying reflected waves to continue communications in the case of line-of-sight signals are interrupted. (iii) Small diameter (less than 6.5 mm) wireless harness systems have been validated with smaller propagation loss than conventional bigger diameter harness systems. (iv) ISWAN (Integrated Services Wide Area Wireless Networks) in 900 MHz band has been proposed to IEEE802.15.4K. The image of ISWAN is shown in Fig.3 aiming to be used for a disaster-relief network in case of emergency as well.

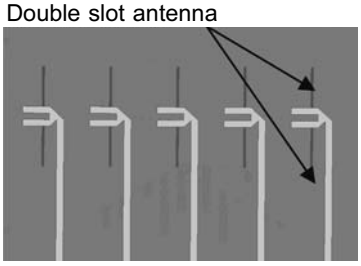


Fig. 1 5-element beam-forming antenna

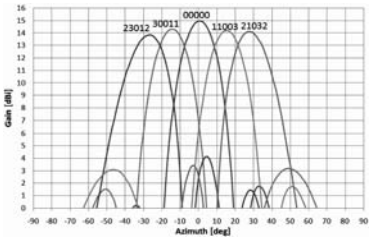


Fig. 2 Antenna directivity (0: 0° , 1:90° ,2: 180° ,3: 270°)

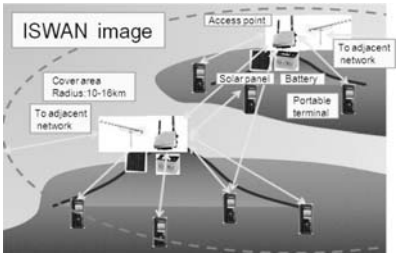


Fig.3 ISAWAN image

[Staff]

Prof.: Shuzo Kato, Ph.D, Associ. Prof: Hiroyuki Nakase, Ph. D, Technical staff: Tuncer Baykas, Shigeru Yoshimiya, Technical assistant: Naomi Aizawa

[Profile]

Shuzo Kato 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 its global (IEEE) standardization lead. Graduated from Faculty of Engineering, Tohoku University with Ph. D in 1977, Published over 200 technical papers and held over 100 patents (including the one that became Department of Defense (USA) standard in 1998), Fellow of the IEEE and IEICE Japan.

Hiroyuki Nakase graduated from Faculty of Engineering, Tohoku University with Ph. D in 1995. After working at NTT Research Laboratories, he has been with RIEC, Tohoku University working on 60GHz CMOS MMICs for super broadband wireless communications and applications from 1999.

[Papers]

1. Hirokazu Sawada, Shunya Takahashi, Shuzo Kato, "Disconnection Probability Improvement by Using Artificial Multi-reflectors for Millimeter-wave Indoor Wireless Communications," Special Issue of IEEE Transactions on Antennas and Propagation, Vol. 61, No. 4, Part II, April, 2013
2. Lawrence Materum, Hirokazu Sawada, Tuncer Baykas, Shuzo Kato,"Radio Channel Power Delay Profile Models for 60 GHz Beam Tracking Systems in a NLoS In-Room Scenario," GSMM2013, April 22-23, 2013, Sendai, Japan.
3. Tuncer Baykas, Lawrence Materum, Shuzo Kato,"Performance of 60 GHz Single Carrier Systems with a Modified Saleh-Valenzuela Channel Model," GSMM2013, April 22-23, 2013, Sendai, Japan.

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. 2010 to Mar. 2011 of these fields except the visitor section is described in this section.

(1) Software Construction

We have been researching on theoretical foundations for flexible yet reliable programming languages, and have been developing SML#, a new programming language in the ML family, that embodies some of our research results. The major results of the 2012 academic year include the following. (1) By using program transformations, we developed efficient sequential and parallel algorithms for finding the maximum-sum subregions. (2) Development of the SML# compiler: We developed (i) an interactive mode implemented on our native code separate compilation scheme, and (ii) an experimental concurrent garbage collector based on our non-moving bitmap marking algorithm. We have also released the first major release of the SML# compiler.

(2) Computing Information Theory

Aiming at combining program transformation methods and automated theorem proving methods, we continued to pursue the possibility of program transformation by templates based on term rewriting. For efficient verification of inductive theorems, which is needed to guarantee the correctness of the program transformation, we gave an abstract principle and applicability conditions of decidability of inductive theorems based on rewriting induction. Although many automated termination provers have been proposed recently, little work is reported on automated confluence provers. We continued to develop an automated confluence prover ACP for term rewriting systems based on several divide-and-conquer methods. We contributed to have the first confluence competition for term rewriting systems, and the tool ACP developed by our group has won first place among the three participants.

(3) Communication Network Systems

A research project of intelligent management support of disaster-resistant ICT unit based on Active Information Resource is launched, and a new management method is proposed and a prototype system is designed and implemented using the repository-based multiagent framework. To realize a user-oriented information delivery mechanism in the disaster, an agent-based method of autonomic cooperation of both telecast contents and web contents is proposed and a prototype system is developed and demonstrated. Moreover, a design method of evolutional agent system had been studied based on the multiagent application systems.

(4) Information Content

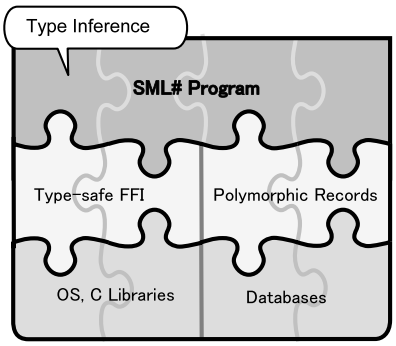
We focus on non-traditional content other than movies, music, and games, conducting comprehensive research on a variety of interactive content which creates new value through interactions with humans. This year we firstly proposed a two-part models of pointing performance in a graphical user interface (GUI), which describes pointing on a computer display significantly better than traditional one-part Fitts's Law models. Secondly, a novel algorithm is proposed that dynamically displays a set of digital photographs with interactively selected principles. In this method, a variety of photograph arrangements can be flexibly achieved based on user needs. In order to achieve such flexibility, we introduced an approach based on emergent computation. Thirdly, we started a collaborative research with social psychologists by developing an experimental media space with large wall displays, floor displays, movable displays, and so on, in order to investigate relationship between the information content displayed in the space and quality of interpersonal communication/interaction.

Ohori 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 2012 academic year include the following. (1) Developments of algorithms for maximum-sum subregion problems: by using program transformations, we developed several efficient sequential and parallel algorithms for finding the maximum-sum subregions. (2) Development of the SML# compiler: We developed (i) an interactive mode implemented on our native code separate compilation scheme, and (ii) an experimental concurrent garbage collector based on our non-moving bitmap marking algorithm. We have also released the first major release of the SML# compiler

[Staff]

Professor : Atsushi Ohori, Dr.
Assistant Professor : Katsuhiro Ueno, Dr.
Assistant Professor : Akimasa Morihata, 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] Akimasa Morihata, Kazuhiko Kakehi, Zhenjiang Hu, Masato Takeichi. Manipulating Accumulative Functions by Swapping Call-time and Return-time Computations, J. Funct. Program., 22(3), 2012.
[2] Isao Sasano, Atsushi Ohori. Embedding the C language into SML#, Computer Software, 29(2), 2012 (in Japanese).
[3] Akimasa Morihata, Calculatinal Developments of New Parallel Algorithms for Size-constrained Maximum-Sum Segment Problems, In Proc. FLOPS 2012, LNCS 7294, 2012.

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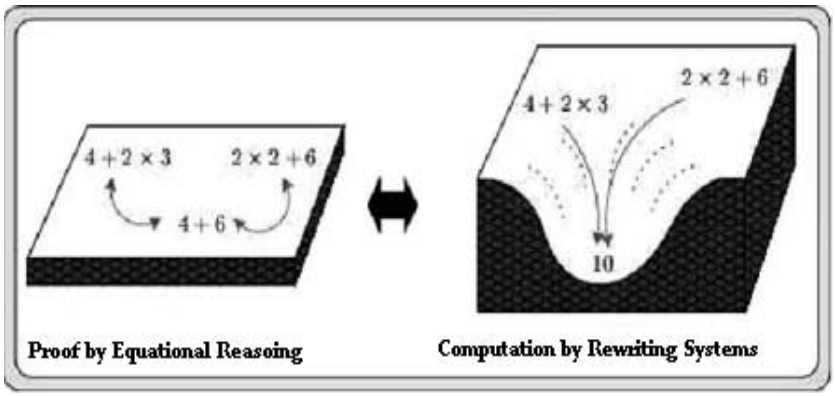
Computing Information Theory
Towards a New Software Paradigm Arising from Computation and Proof

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 : Yoshihito Toyama, Dr
Associate Professor : Takahito Aoto, Dr
Assistant Professor : Kentaro Kikuchi, 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)Yuki Chiba and Takahito Aoto,Transformations by templates for simply-typed term rewriting,In Proceedings of the 6th International Workshop on Higher-Order Rewriting(HOR 2012), pp.3-8, 2012.

(2) Takahito Aoto and Jeroen Ketema, Rational term rewriting revisited:decidability and confluence, In Proceedings of the 6th InternationalConference on Graph Transformation (ICGT 2012), Lecture Notes in Computer Science, Vol.7562, pp.172-186, 2012.

(3)Masaki Matoba, Takahito Aoto and Yoshihito Toyama,Commutativity of term rewriting systems based on one side decreasing diagrams (in Japanese), Computer Software, Vol.30, No.1, pp.187-202, 2013.

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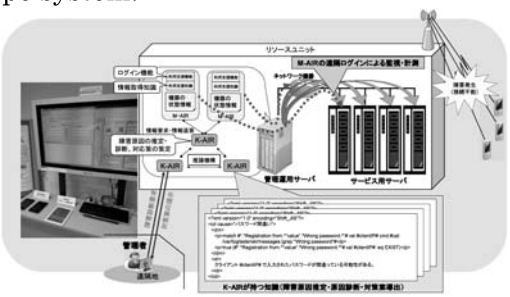
Communication Network Systems

Support for Cooperation and Communication between Human and Systems

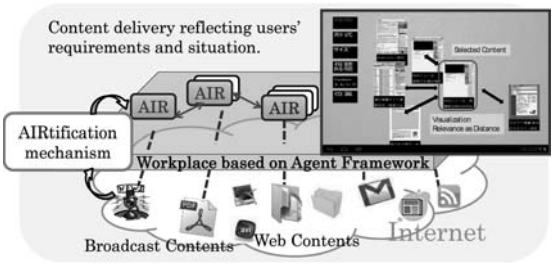
Intelligent Communication : Tetsuo Kinoshita, Professor
Intelligent Network : Gen Kitagata, Associate Professor

[Research Target and Activities]

In this year, the following studies have been done. (a) Evolutional Agent Systems: A situation monitoring function which monitors the operating conditions of multiagent sytems has been designed and implemented. (b) Knowledge-based Management and Operation Support: A method for accumulating and monitoring distributed network information and for supporting operational management for disaster-resistant ICT has been proposed and evaluated based on a prototype system (AIR-NMS). (c) Information Delivery Support Mechanism: A method for the support of accumulation and integration of distributed information resource has been proposed and evaluated through a prototype system.



Knowledge-based management and operation support for disaster-resistant ICT units



Information delivery support mechanism based on autonomous cooperation among contents

Multiagent-based Support for Cooperation and Communication between Human and Systems

[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. His research interests include agent engineering, knowledge engineering, knowledge-based systems and agent-based systems. He received the IPSJ Research Award, the IPSJ Best Paper Award and the IEICE Achievement Award in 1989, 1997 and 2001, respectively. 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] Y. Lim, H.-M. Kim, T. Kinoshita, "Traffic Rerouting Strategy against Jamming Attacks in WSNs for Microgrid," International Journal of Distributed Sensor Networks, Vol.2012, pp.1-7, 2012.
[2] K. Kalegele, H. Takahashi, K. Sasai, G. Kitagata, T. Kinoshita, "Sequence Validation Based Extraction of Named High Cardinality Entities," International Journal of Intelligence Science (IJIS), Vol.2, No.24, pp.190-202, 2012.
[3] Y. Lim, H.-M. Kim, T. Kinoshita, "Cooperative Load-Shedding Control of Agent-based Islanded Microgrid," Advances in information Sciences and Service Sciences (AISS), No.18, pp.271-280, 2012.

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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 mid-air and gestural interactions, media-space for enhancing inter-personal communication, novel multi-touch interaction with content distortion, so on.

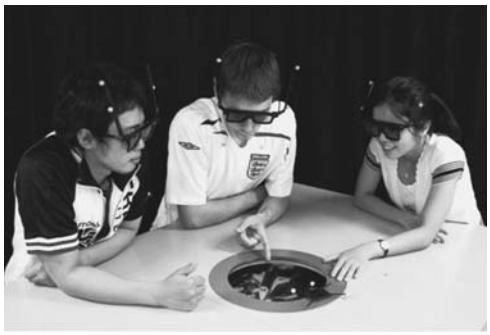

Fig. 1: Direct multi-touch interface on stereoscopic tabletop display

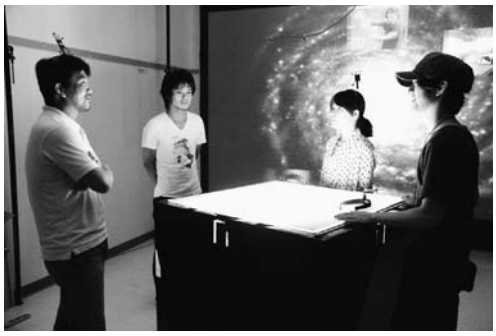

Fig. 2: Media space for enhanced inter-personalcommunication

[Staff]

Professor: Yoshifumi Kitamura, Dr.
Assistant Professor: Kazuki Takashima, Dr.
Research Fellow: Hitomi Yokoyama, Dr.

[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] Garth Shoemaker, Takayuki Tsukitani, Yoshifumi Kitamura, and Kellogg S. Booth, "Two-part models capture the impact of gain on pointing performance", ACM Transactions on Computer-Human Interaction (TOCHI), Vol. 19, Issue 4, pp. 28:1-28:30, 2012

[2] Hitomi Yokoyama, Ikuo Daibo, "Effects of gaze and speech rate on receivers' evaluations of persuasive speech", Psychological Reports, Vol. 110, pp. 663-676, 2012.

[3] Kazuki Takashima, Kazuyuki Fujita, Yuichi Itoh, Yoshifumi Kitamura, "Elastic scroll for multi-focus interactions", Adjunct proceedings of the 25th annual ACM symposium on User interface software and technology (UIST 2012), pp. 19-20, 2012.

Information Social Structure

Disaster-resilient Green ICT for Symbiosis between Humans' Life and Natural Environment

[Research Target and Activities]

In 21st century, we are facing with global environmental "changes" including global warming and social structural "changes" such as aging of the population. To absorb and harmonize these changes, we proposed a new computation paradigm, the concept of "Symbiotic computing", in 1992. This idea places on values on harmony between "Agents" (e.g. human, computer, internet, robot, nature, country, culture and etc.). From the engineering point of view, we have been pursuing researches on the "Symbiotic computing" which are its model, design and applications (Fig.1).

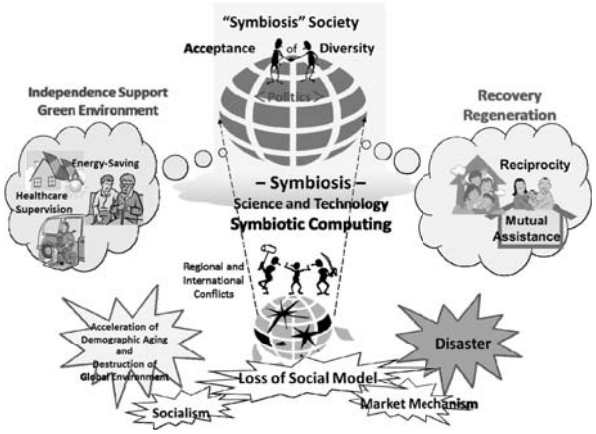

Fig.1: Model of Symbiotic Information Society

Based on the idea of "Symbiotic Computing," we have been conducting the Green ICT Innovation Promotion (PREDICT) since 2011, a three year cooperative project (2011-2014) funded by the Ministry of Internal Affairs and Communications, Japan. In this project, we have been investigating our originally developed "Green-oriented Never Die Network Management Technology" ahead of the rest of the world. It achieves greening (the reduction of CO_2 emissions by power saving) of the entire information system and high disaster resilience at the same time.

Our project goal is to reduce CO2 emissions, and to construct the infrastructure of information and communication systems with fault-tolerance in the event of a natural disaster, by effectively configuring wired and wireless networks. We also propose G-MIB (Green-oriented Management Information Base) to collect and control information to express working status of PCs effectively for energy saving of the entire information system. In IETF, we are engaged in international standardization activities of our proposed MIB through the promotion of its research and development.

[Staff]

Professor: Shiratori, Norio Dr.

Research Fellow: Izumi, Satoru Dr. Secretary: Horino, Midori

[Profile]

Prof. Shiratori was bone in 1946 in Miyagi Prefecture. He received his doctoral degree from Tohoku University in 1977. He is currently a Visiting Professor at RIEC, a Professor Emeritus at Tohoku University, an Administration Officer at Future University Hakodate, and a Professor at GITS, Waseda University. Before moving to RIEC in 1993, he was the Professor of Information Engineering at Tohoku University from 1990 to 1993. Prior to that, he served as an Associate Professor and Research Associate at RIEC. He received IEEE Fellow in 1998, IPSJ Fellow in 2000 and IEICE Fellow in 2002. He is the recipient of many awards including, IPSJ Memorial Prize Wining Paper Award in 1985, IPSJ Best Paper Award in 1996, IPSJ Contribution Award in 2007, IEICE Achievement Award in 2001, IEICE Best Paper Award, IEEE ICOIN-11 Best Paper Award in 1997, IEEE ICOIN-12 Best Paper Award in 1998, IEEE ICPADS Best Paper Award in 2000, IEEE 5-th WMSCI Best Paper Award in 2001, UIC-07 Outstanding Paper Award in 2007, Telecommunication Advancement Foundation Incorporation Award in 1991, Tohoku Bureau of Telecommunications Award in 2002, The Commendation for Science and Technology by the MEXT, in 2009, Distinguished Achievement and Contributions Award of IEICE in 2011, etc. He was the vice president of IPSJ in 2002, IFIP representative from Japan in 2002, an associate member of Science Council of Japan in 2007, president of IPSJ in 2009, and Honorary Member of IEICE in 2012. He is working on methodology and technology for symbiosis of human and IT environment.

[Papers]

[1] N. Shiratori, T. Inaba, N. Nakamura, and T. Suganuma, "Disaster-resistant Green-oriented Never Die Network," IPSJ **Journal**, Vol.53, No.7, 1821-1831, July, 2012. (**Invited Paper**)

[2] N. Shiratori, N. Uchida, Y. Shibata, and S. Izumi, "Never Die Network towards Disaster-resistant Information Communication Systems," ASEAN Engineering **Journal** Part D, Vol.1, No.2, pp.1-22, March, 2013. (**Invited Paper)**

[3] N. Shiratori, "Year 2020: Symbiotic Computing towards Post-Modern Information System - Symbiosis between Information Systems and Nature -," IEEE International Symposium on Information Technology in Medicine and Education (ITME 2012), August, 2012. (**Keynote Speech**)

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3-5. Environmental-Adaptive Information and Communication Engineering: goals and achievements in 2012

To embody a humanity-rich-communication by innovating information-and-communication technology (ICT) in the sustainable global society, we have to create human-friendly low-environmental-impact ICT devices and systems by using electronic materials and device-technology in the research fields of Nanotechnology, Spintronics and Information technology. Our aim is that the embodiment of low-environmental-impact information devices and electronic equipments based on fundamental theory of spin and electron; these are designed by systematic survey of the rapidly-changing industry needs and R&D trends. We report the summary of our activities in 2012.

Research

The biggest Tsunami induced by the mega-earthquake destroyed the 4 nuclear plants in Fukushima at 11 March 2011. The destruction caused scattering of radioactive materials onto Fukushima and neighboring prefectures. This radioactive environmental pollution will affect our daily life over 30 years at least. We must remove the pollution or otherwise reduce deleterious effect on our daily life as far as possible. For this purpose, we have started to research a low-cost-high-sensitivity visualization device for detecting γ -ray exposure, using plate-like silver nanoparticles adhered on plate-like α-alumina powder being developed.

Achievement

The lowest γ-ray dose for discoloration of the powder had been estimated as 30 Gy ~ 300 Gy. However this sensitivity is not enough to detect the radioactive materials scattered to the land of Fukushima prefecture. We have tried to make the discoloration sensitivity high (up to 0.1mGy in the best case) by using microcapsules holding hydrogen peroxide inside together with the powders. It seems this microcapsule made of polymer blend releases hydrogen peroxide by applying gamma-ray irradiation in the range of 1 - 7 mGy (^{137}Cs). Although the blend is not enough adjusted yet for γ-ray sensitivity and barrier function, we think that the high sensitive gamma-ray detection using chemical processes can be possible.

Environmental-Adaptive Information and Communication Engineering

Does it contain Wisdom?

Environmental-Adaptive Information and Communication Engineering Eiki Adachi, Professor

[Research Target and Activities]

Research target: To embody a humanity-rich-communication by innovating information-and-communication technology (ICT) in the sustainable global society, we have to create human-friendly low-environmental-impact ICT devices and systems by using electronic materials and device-technology in the research fields of Nanotechnology, Spintronics and Information technology. Our aim is that the embodiment of low-environmental-impact information devices and electronic equipments based on fundamental theory of spin and electron; these are designed by systematic survey of the rapidly-changing industry needs and R&D trends.

Activities: The biggest Tsunami induced by the mega-earthquake destroyed the 4 nuclear plants in Fukushima at 11 March 2011. The destruction caused scattering of radioactive materials onto Fukushima and neighboring prefectures. This radioactive environmental pollution will affect our daily life over 30 years at least. We must remove the pollution or otherwise reduce deleterious effect on our daily life as far as possible. For this purpose, we have started to research a low-cost-high-sensitivity visualization device for detecting gamma-ray exposure, using our nanostructured material being developed. The lowest gamma-ray dose for discoloration of plate-like silver nanoparticles adhered on plate-like α-alumina powder was estimated as 30 Gy ~ 300 Gy. However this sensitivity is not enough to detect the radioactive materials scattered to the land of Fukushima prefecture. Therefore we have tried to make the discoloration sensitivity high (up to 0.1mGy in the best case) by using microcapsules holding hydrogen peroxide inside together with the powders. It seems this microcapsule made of polymer blend releases hydrogen peroxide by applying gamma-ray irradiation in the range of 1 - 7 mGy (^{137}Cs). Although the blend is not enough adjusted yet for γ-ray sensitivity and barrier function, we think that the high sensitive gamma-ray detection using chemical processes can be possible.

[Staff]

Professor: Adachi Eiki PhD.

[Profile]

Eiki Adachi, Education: B.S. in Physics (Saitama University, May 1989), M.S. in Physics (Tokyo Institute of Technology, May 1991), Ph.D. (Tokyo University, May 1996). History of employment: ERATO project, National institute of physiological sciences, L'ORÉAL Tsukuba center, Fuji electric advanced technology Co., Ltd., Fuji electric holdings Co., Ltd., Professor, Research Institute of Electrical Communication (Tohoku University, May 2010~). Research field: Synthesis of nanomaterials and its application for communication technology.

[Papers]

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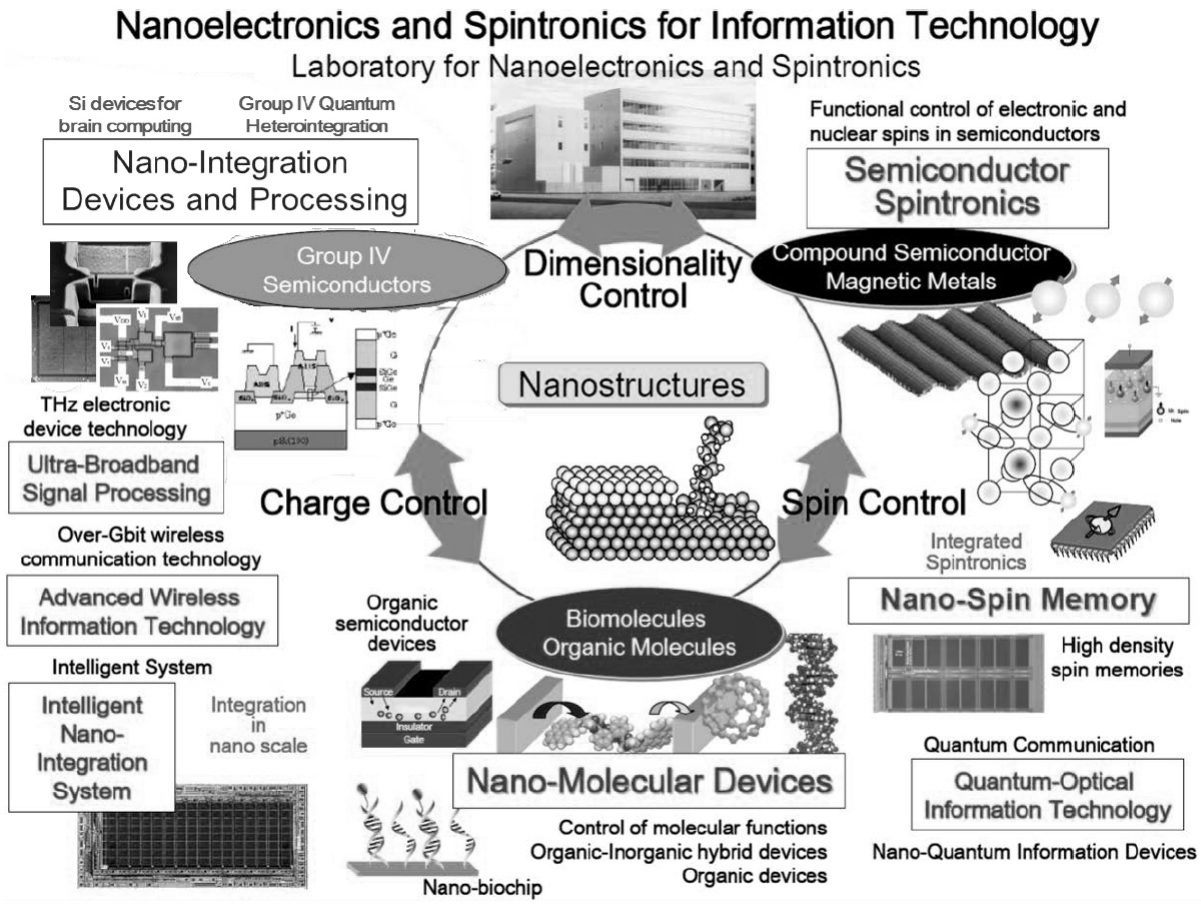
Laboratory for Nanoelectronics and Spintronics

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 2012

Nano Integration

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

(1) Digital neural network circuit using stochastic logic has been designed and implemented on an FPGA for its application to combinatorial optimization problems. We calculate synaptic weights dynamically and do not store such weights to save memory usage, and confirm such technique works successfully. Moreover, we have analyzed quantum properties of superconducting qubits proposed so far in order to implement a qubit or a quantum neuron. Research direction for device design including quantum state control and biasing has been obtained for multi-bit implementation.

(2) Epitaxial growth using low-energy ECR plasma CVD without substrate heating has been studied. It is found that Ge fraction in $Si_{1-x}Ge_x$ alloy films on Si(100) can be controlled widely by change of reactant gas flow ratio of SiH_4 and GeH_4. Moreover, epitaxial growth of B-doped Si films with extremely high B concentration has been enabled, and carrier concentration higher than 10^{18} cm^{-3} can be obtained by low-temperature heat treatment at 200-300°C after deposition. Additionally, epitaxial growth of B-doped Ge films with higher B concentration than 5% has been enabled on Si(100).

● Intelligent Nano-Integration System (K. Nakajima)

(1) By using high-order synapses for an inverse function delayed neural network, we theoretically obtained the parameter values that presented optimal solutions only for traveling salesman and quadratic assignment problems. Furthermore, we proposed a generalized energy function for scheduling problems and an inverse function delay-less model for high speed numerical calculation of artificial neural networks. (2) We also proposed new analyses based on the relationship among a potential and active regions for nonlinear dynamics, in which bursting oscillations were analyzed and designed. (3) We studied a possibility of superconducting plural bits realization in the quantum bits computation algorithm. We demonstrated successfully a 4-bit parallel multiplier using a carry look-ahead adder with niobium integrated circuits to improve the performance of high-speed operation for the single flux-quantum fast Fourier transform and designed an 8-bit parallel multiplier. A neural network using superconducting quantum interference devices was fabricated and successfully demonstrated.

Semiconductor Spintronics and Information Technology

● Semiconductor Spintronics and Nano-Spin Memory (H. Ohno and S. Ikeda)

Our research activities focus on the establishment of fundamental technologies for future spintronics devices. The outcomes in the last fiscal year are following. (1) Demonstration of coherent control of nuclear spins with an electric field, focusing on ^{75}As as a target nucleus. (2) Demonstration of electric field-induced ~180° magnetization reversal in a CoFeB/MgO based magnetic tunnel junction with a perpendicular magnetic easy axis (p-MTJ). (3) Demonstration of spatial control of the magnetic anisotropy of perpendicularly magnetized CoFeB/MgO films by etching a fraction of the MgO overlayer. (4) B composition dependence of magnetic anisotropy in MgO/CoFe(B) stack structures was clarified. (5) Discovery of proportionality between thermal stability factor and thickness of a recording layer in p-MTJ with the size larger than nucleation diameter. (6) Development of p-MTJs with a double interface MgO/CoFeB/Ta/CoFeB/MgO recording structure.

1. Research activities in "Research and development of ultra-low power spintronics-based VLSIs" under granted by JSPS through the FIRST program. (1) Development of a CoFeB based p-MTJ with 29 nm in diameter, which shows thermal stability factor of 59, by using a double interface MgO/CoFeB/Ta/CoFeB/MgO recording layer and synthetic ferrimagnetic reference layer. (2) Observation of tunneling magnetoresistance at room temperature in p-MTJ with $L1_0$-ordered MnAl electrodes. (3) Demonstration of high speed switching less than 1 ns in p-MTJ with 40 nm in diameter. (4) Fabrication of 1Mb STT-RAM and image processing circuit based on fine-grain power gating. (5) Fabrication and verification of basic operation of 4T-2MTJ nonvolatile ternary content-addressable memory (TCAM) cell.
2. 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) Fabrication of p-MTJs for irradiation experiment. (2) Fabrication of spintronics devices for high-speed switching measurement.

● Ultra-Broadband Signal Processing (T. Otsuji and T. Suemitsu)

The goal of our research is to explore the terahertz frequency range by creating novel electron devices and systems. Graphene, a monolayer sheet of honeycomb carbon crystal, exhibits unique carrier transport properties owing to the massless and gapless energy spectra, which is expected to break through the limit on conventional device operating speed/frequency performances. First, we have theoretically discovered giant gain

enhancement of surface plasmon polaritons in THz range in population-inverted graphene, monolayer of carbon atomic honeycomb crystal, by whose extraordinary carrier transport properties we proposed a novel THz lasers and experimentally verified stimulated THz emission at room temperature. Second, we devised novel plasmon-resonant THz emitter/detector devices, succeeding in world-first coherent monochromatic THz plasmonic lasing and breaking the record sensitivity to 6.4 kV/W at 1.5-THz radiation.

● Quantum-Optical Information Technology (K. Edamatsu, H. Kosaka and Y. Mitsumori)

1. We are developing novel and efficient entangled-photon sources. We have demonstrated (1) generation and activation of four-photon bound entanglement, (2) quantum multi-photon interference in telecom wavelength, and (3) efficient photon pair generation from silicon wire waveguides.

2. We are developing a quantum media converter from a photon to an electron spin to realize a quantum repeater, which is expected to extend the transmission distance of quantum info-communication. We have demonstrated that (1) the process of state transfer is quantum like by the measurement of electron spin state tomography, and (2) fundamental experiments for the photonic state transfer to a quantum memory in diamond.

3. We have investigated the excitonic Rabi oscillations in semiconductor quantum dots using photon echo spectroscopy for the development of the optical coherent control of the electric states in the quantum dots. We have observed the interesting behavior of the Rabi oscillations arising from the local field effect in the quantum dots.

Nano-Molecular Devices

● Nano-Molecular Devices (M. Niwano and Y. Kimura)

1. Elucidation of anodization process of titanium

The anodization process of Ti is a useful method to form vertically oriented TiO_2 nanotube films and an ammonium fluoride (NH_4F) containing organic solution is used as an electrolyte. The formation process and the structure of anodic TiO_2 nanotubes depend strongly on component of electrolyte. We investigated influence of concentrations of NH_4F and water in the organic electrolyte on the growth rate of TiO_2 nanotube films. We found that a ratio of the concentration of NH_4F to that of water plays an important role in the anodization process of Ti. This indicates that the structure of anodic TiO_2 nanotubes can be controlled by an electrolyte. (published in JES)

2. Fabrication of micro TiO_2 gas sensors through local anodization

We demonstrated fabrication of a micro gas sensor of 2×2 μm^2 through local anodization which is a hybrid process between the photolithography technique and the anodization process. The sensitivity and the linearity were improved by thinning walls of anodic TiO_2 nanotubes. This indicates that the local anodization is a suitable method for miniaturization of gas sensors and reduction in power consumption and development of a simultaneous multi-component gas sensing system are expected. (published in Sens. and Actuators B)

3. Reconstitution of hERG channels in microfabricated Si chips

We have succeeded in reconstitution of human ether-a-go-go-related gene (hERG) channels in stable bilayer lipid membranes (BLMs) formed in micropores fabricated in Si chips. Characteristic features of hERG channels, including single-channel conductance and sensitivity to typical drugs, were observed, demonstrating intact incorporation of hERG in the Si chips. The hERG channel has been drawing a lot of pharmacological attention because it has been found to cause serious arrhythmic side effects. The next step is to extend the hERG-containing stable BLM device to a multi-site array format. The realization of a hERG-channel array will open a variety of applications, including high-throughput drug safety screening procedures. (published in Anal. Chem.)

Nano-Integration Devices and Processing

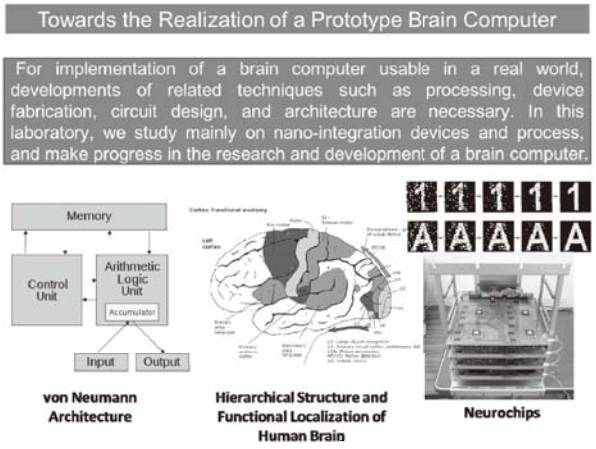
Nano-integration beyond the existing technology

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) Digital neural network circuit using stochastic logic has been designed and implemented on an FPGA for its application to combinatorial optimization problems. (2) By using low-energy ECR plasma CVD, epitaxial growth of Si and Ge films with extremely high B concentration and $Si_{1-x}Ge_x$ alloy has been realized without substrate heating.



Towards the Realization of a Prototype Brain Computer

[Staff]

Professor : Shigeo Sato, Dr.
Associate Professor : Masao Sakuraba, 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.

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] “Designing Method of Energy Functions for Solving Combinatorial Optimization Problems by Using the Inverse Function Delayed Network with Higher-Order Connections”, T. Sota, Y. Hayakawa, S. Sato, K. Nakajima, IEICE Trans. Fundamentals, Vol. J96-A, No. 1, pp.12-21, 2013 (in Japanese).
[2] “Epitaxial Growth of $Si_{1-x}Ge_x$ on Si(100) by ECR Ar Plasma CVD from SiH_4-GeH_4 Gas Mixture without Substrate Heating”, N. Ueno, M. Sakuraba, J. Murota and S. Sato, 6th Int. WorkShop on New Group IV Semiconductor Nanoelectronics and JSPS Core-to-Core Program Joint Seminar "Atomically Controlled Processing for Ultralarge Scale Integration", Tohoku Univ., Sendai, Japan, Feb. 22-23, 2013, Abs.No.P-17.

Contact to Professor Shigeo Sato : shigeo@riec.tohoku.ac.jp

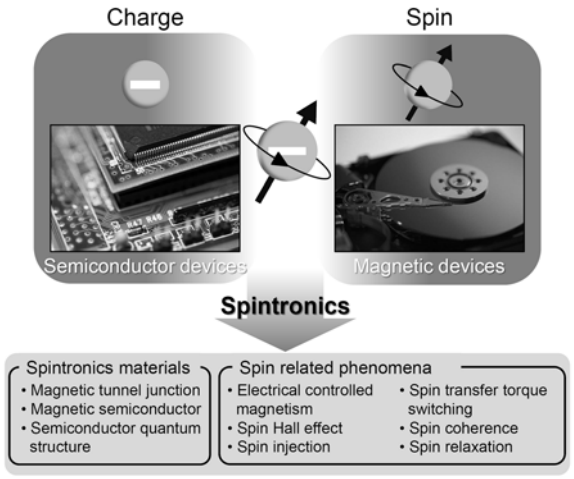
Semiconductor Spintronics

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, development of spintronic devices with the size of less than 20 nm and their processing technology, characterization of the fabricated spintronic devices, and fabrication of various prototype integrated circuits employing spintronic devices.



The outcomes in the last fiscal year are (1) Demonstration of coherent control of nuclear spins with an electric field, focusing on ^{75}As as a target nucleus. (2) Demonstration of electric field-induced ~180° magnetization reversal in a CoFeB/MgO based magnetic tunnel junction with a perpendicular magnetic easy axis. (3) Discovery of spatial control of the magnetic anisotropy of perpendicularly magnetized CoFeB/MgO films by etching a fraction of the MgO overlayer.

[Staff]

Professor: Hideo Ohno, Dr.
Research Fellow: Lin Chen, Dr.
Research Fellow: Norikazu Ohshima, Dr.
Assistant Professor: Michihiko Yamanouchi, Dr.
Research Fellow: Tadashi Yamamoto, BE

[Profile of Professor Hideo Ohno]

Hideo Ohno received 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] M. Ono, J. Ishihara, G. Sato, Y. Ohno, and H. Ohno, "Coherent Manipulation of Nuclear Spins in Semiconductors with an Electric Field," Applied Physics Express, Vol. 6, 033002 (3 pages), February 2013.
[2] S. Kanai, M. Yamanouchi, S. Ikeda, Y. Nakatani, F. Matsukura, and H. Ohno, "Electric field-induced magnetization reversal in a perpendicular-anisotropy CoFeB-MgO magnetic tunnel junction," Applied Physics Letters, Vol. 101, 122403 (3 pages), September 2012.
[3] M. Hayashi, M. Yamanouchi, S. Fukami, J. Sinha, S. Mitani, and H. Ohno, "Spatial control of magnetic anisotropy for current induced domain wall injection in perpendicularly magnetized CoFeB/MgO nanostructures," Applied Physics Letters, Vol. 100, 192411 (4 pages), May 2012.

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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
Nano-Electron Devices: Yasuo Kimura, Associate Professor

[Research Target and Activities]

Our research aims at application of semiconductor micro/nano-fabrication to semiconductor devices or many kinds of biosensors. We have investigated development of 1) a biomolecular sensing system using Si fabrication technologies and 2) a nanofabrication method using electrochemical processes such as anodization of valve metals.

1) Elucidation of anodization process of titanium

We investigated influence of concentrations of NH_4F and water in the organic electrolyte on the growth rate of TiO_2 nanotube films and demonstrated that the structure of anodic TiO_2 nanotubes were controlled by the electrolyte composition.

2) Fabrication of micro TiO_2 gas sensors through local anodization

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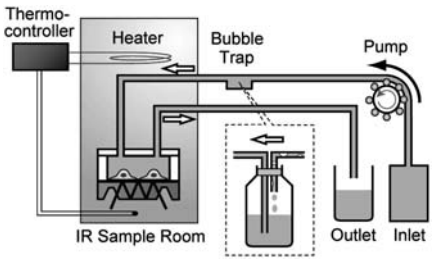
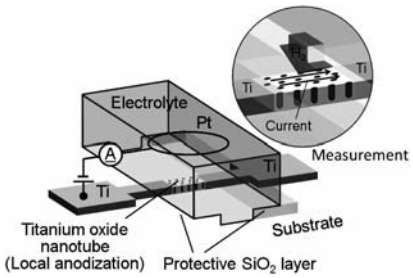


Experimental system for *in situ* monitoring of cell activity by surface infrared spectroscopy



Local anodization and the structure of a micro TiO_2 nanotube hydrogen sensor

[Staff]

Professor: Michio Niwano,Dr.
Associate Professor: Yasuo Kimura,Dr.
Assistant Professor: Yuki Aonuma,Dr.

[Profile]

Michio Niwano 1998 – present RIEC, Tohoku University, Japan, Professor, Doctorate of Science
Memberships: The Electrochemical Society (ECS), The Material Research Society (MRS), American Vacuum Society (AVS), The Japan Society of Applied Physics (JSAP)

Yasuo Kimura 2010 – present RIEC, Tohoku University, Japan, Associate Professor, Ph. D. Eng.
Memberships: The Electrochemical Society (ECS), The Japan Society of Applied Physics (JSAP), The Surface Science Society of Japan

[Papers]

[1] Ryota Kojima, Yasuo Kimura, Mitsuo Bitoh, Munemitsu Abe, Michio Niwano, "Investigation of Influence of Electrolyte Composition on Formation of Anodic Titanium Oxide Nanotube Films", J. Electrochem. Soc. **159** (11), (2012) D629-D636.

[2] Yasuo Kimura, Shota Kimura, Ryota Kojima, Mitsuo Bitoh, Munemitsu Abe, and Michio Niwano, "Micro-scaled hydrogen gas sensors with patterned anodic titanium oxide nanotube film", Sens. Actuators B **177** (2013) 1156-1160

[3] A. Oshima, Ayumi Hirano-Iwata, Hideki Mozumi, Yutaka Ishinari, Yasuo Kimura, and Michio Niwano, "Reconstitution of Human Ether-a-go-go-Related Gene Channels in Microfabricated Silicon Chips", Anal. Chem. **85** (2013) 4363-4369.

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Nano-Spin Memory

Research of spin based device and memory

Nano-Spin Memory Shoji Ikeda, Associate Professor

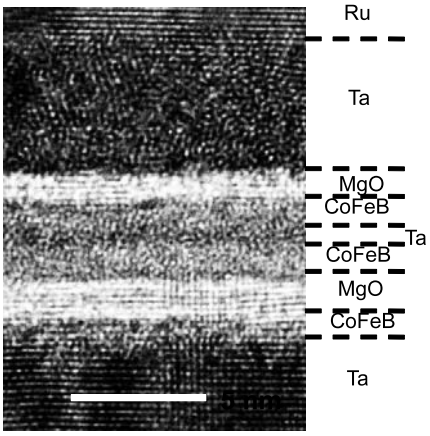
[Research Target and Activities]

We are developing technologies to realize advanced spin memory and logic devices using magnetic tunnel junctions (MTJs). In our group, the following results were obtained.

1) We investigated B composition dependence of magnetic anisotropy and TMR ratio in MgO/CoFe(B) stack structures with different CoFe(B) compositions of top electrode. The effective magnetic anisotropy energy density shows a maximum value in the stack structure with $Co_{20}Fe_{60}B_{20}$ composition.

2) We studied thermal stability in perpendicular anisotropy CoFeB/MgO magnetic tunnel junctions (p-MTJs) with various CoFeB recording layer thicknesses. The values of thermal stability in a larger junction size range than nucleation size increase linearly as the recording layer thickness increases.

3) We developed p-MTJs with double interface MgO/CoFeB/Ta/CoFeB/MgO recording layer. The thermal stability of p-MTJ with 70 nmϕ increases up to 95 in a larger junction size range than nucleation size, while keeping comparable intrinsic critical current with comparison to single interface CoFeB/MgO recording layer structure.



Cross sectional transmission electron microscope image of perpendicular anisotropy magnetic tunnel junction (p-MTJ) with double interface MgO/CoFeB/Ta/CoFeB/MgO recording layer.

[Staff]

Associate Professor : Shoji Ikeda, Ph.D.
Research Fellow : Tadashi Yamamoto
Research Fellow : Norikazu Ohshima, Ph.D.

[Profile]

Shoji IKEDA received the B.S., M.S., and Ph. D degrees from Muroran Institute of Technology, Muroran, Japan, in 1991, 1993 and 1996, respectively. He was a Research Associate with the Department of Electrical and Electronic Engineering at the Muroran Institute of Technology from 1996 to 1999. He was with Fujitsu Limited, Atsugi/Nagano, Japan, from 1999 to 2003. He joined Tohoku University, Sendai, Japan, in 2003, where he is currently an Associate Professor. His current research interests include magnetic metal devices with nanostructures and their application. He received the Magnetics Society of Japan Distinguished Paper Award in 2003, the APEX/JJAP Paper Award in 2009, DPS Best Paper Award in 2011, and SSDM Paper Award in 2012.

[Papers]

[1] S. Ikeda, R. Koizumi , H. Sato, M. Yamanouchi, K. Miura, K. Mizunuma, H. D. Gan, F. Matsukura, and H. Ohno, "Boron composition dependence of magnetic anisotropy and tunnel magnetoresistance in MgO/CoFe(B) based stack structures", IEEE Transactions on Magnetics, Vol. 48, 3829, October 2012.

[2] H. Sato, M. Yamanouchi, S. Ikeda, S. Fukami, F. Matsukura, and H. Ohno, "Perpendicular-anisotropy CoFeB-MgO magnetic tunnel junctions with a MgO/CoFeB/Ta/CoFeB/MgO recording structure", Applied Physics Letters, Vol. 101, 022414, July 2012.

[3] H. Sato, M. Yamanouchi, K. Miura, S. Ikeda, R. Koizumi, F. Matsukura, and H. Ohno, "CoFeB thickness dependence of thermal stability factor in CoFeB/MgO perpendicular magnetic tunnel junctions," IEEE Magnetics Letters, Vol. 3, 3000204, April 2012.

Laboratory for Brainware Systems

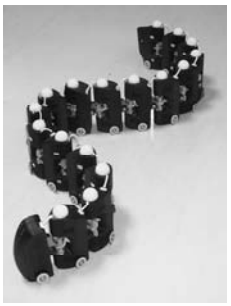
Research Targets and Activities of Laboratory for Brainware Systems

The Laboratory for Brainware Systems of the Research Institute of Electrical Communication was established in 2004. 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 for Real-World Computing (section), New Paradigm VLSI System (section), Intelligent Nano-Integration System (section), Microarchitecture (section), Cyber Robotics (planned section), and Next-Generation Human Interface (planned section). The Laboratory for Brainware Systems consists of the above six sections 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.

Physical and Adaptive Hardware Environment

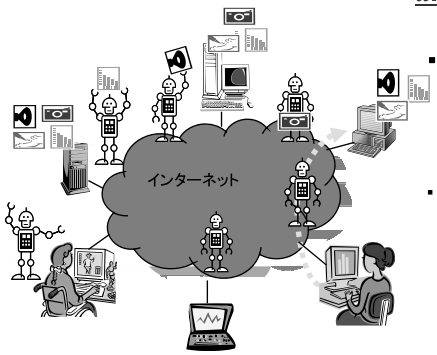


▪ **Real-World Dynamical Intelligence**

（Real-World Computing）

▪ **Virtual Space Construction**

（Cyber Robotics）



Seamless Fusion of Real World and Multi-Modal Computing

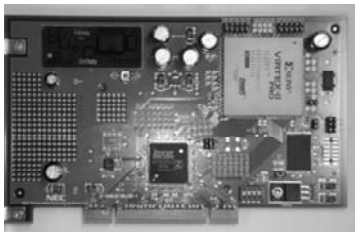
▪ **Human-Machine Cohabitation Architecture**

（Next-Generation Human Interface）

▪ **Higher-Order Multimodal Perception and Information Generation**

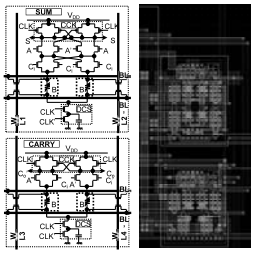
（Multi-Modal Computing）

Hardware Environment with Massively Parallel Brain LSI



▪ **Massively Parallel Neural LSI**

（Intelligent Nano-Integration System）



▪ **Nonvolatile Logic and Its Applications**

（New Paradigm VLSI System）

[Research Target]

Real-World Computing Section: Living organisms exhibit surprisingly adaptive and versatile behavior in real time under unpredictable and unstructured real world constraints 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 investigate the design principle of autonomous decentralized systems that exhibit life-like resilient behaviors from the viewpoints of robotics, mathematics, nonlinear science, and physics.

New Paradigm VLSI System Section Section: Performance degradation of System on a Chip (SoC) or Network on Chip (NoC) due to wiring complexity, power dissipation and characteristic variation of materials/devices is increasingly getting a serious problem in recent VLSI era. Our research activity is to solve the above problem by the following two ways: the use of

logic-in-memory architecture based on nonvolatile storage elements combined with CMOS logic, and the use of asynchronous data-transfer scheme 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.

[Research Activities]

Real-World Computing Section (Ishiguro Laboratory):

The main contributions achieved in 2012 are summarized as follows: (1) We have developed a fully decentralized modular robot that exhibits versatile oscillatory patterns according to the situation encountered, inspired by the plasmodium of true slime mold; (2) We have developed a snake-like robot that exhibits scaffold-based locomotion effectively with the use of local sensory feedback mechanism. (3) We have constructed a novel CPG model, which relies more on physical communication between the limbs rather than neural communication. We have investigated the validity of this model by taking quadruped and hexapod locomotion as practical examples. (4) We have developed a 2D sheet-like robot driven by a decentralized control mechanism with local sensory feedback. The robot could successfully realize multi-terrestrial locomotion, on the ground and in water. (5) We have modeled a neural circuit for the omni-directional resilient locomotion of Ophiuroids. Despite its simplicity, the model well reproduces the innate behavior of the Ophiuroid.

New Paradigm VLSI System Section (Hanyu Laboratory):

We have successfully designed and fabricated a standby-power-free ternary CAM (TCAM) using nonvolatile storage devices; MTJ devices for performing a parallel data-search operation. The nonvolatile TCAM cell circuit consists of four MOS transistors and two MTJ devices (4T-2MTJ structure), which is the minimum number of device counts as a TCAM cell. A new MTJ-based nonvolatile binary CAM (BCAM) is also designed for accelerating cell-circuit area, where the BCAM cell circuit consists of a single MOS transistor and 2 MTJ devices (1T-2MTJ structure). We have also designed a new nonvolatile LUT (look-up table) circuit using 3-terminal MTJ devices (domain-wall motion-based devices). The use of 3-terminal MTJ devices makes design-window constraint relax, because read current level of each MTJ device is independent of its write current level. Moreover, we have designed and fabricated an MTJ-based hardware accelerator LSI for motion-vector extraction as a typical example of MTJ-based logic-LSI applications. In order to design such a large-scaled MTJ-based logic LSI chip, our research group has also developed an MTJ-oriented VLSI CAD tool. Furthermore, we have also designed a high-performance and low-energy CAM for network routing by asynchronous control. Since mismatch states are easily detected by checking the first few bits in each search word, almost all the pattern matching operations in CAM can be negligible. In fact, the proposed CAM operates with about six-times faster than a synchronous CAM with about 40 percent energy saving.

Intelligent Nano-Integration System Section (Nakajima-Sato Laboratory):

(1) By using high-order synapses for an inverse function delayed neural network, we theoretically obtained the parameter values that presented optimal solutions only for traveling salesman and quadratic assignment problems. Furthermore, we proposed a generalized energy function for scheduling problems and an inverse function delay-less model for high speed numerical calculation of artificial neural networks. (2) We also proposed new analyses based on the relationship among a potential function and active regions for nonlinear dynamics, in which bursting oscillations were analyzed and designed. (3) We demonstrated successfully a 4-bit parallel multiplier using a carry look-ahead adder with niobium integrated circuits to improve the performance of high-speed operation for the single flux-quantum fast Fourier transform and designed a 8-bit parallel multiplier. A neural network using superconducting quantum interference devices was fabricated and successfully demonstrated.

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.

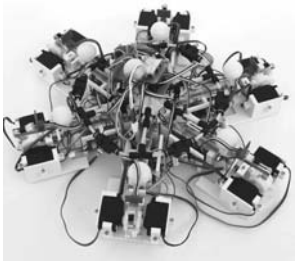


Fig.1: Soft-bodied amoeboid robot driven by a fully decentralized control scheme extracted from true slime mold

Fig.2: Snake-like robot driven by a decentralized control that exhibits adaptive scaffold-based locomotion

Fig.3: Hexapod robot driven by a fully decentralized neural network-based control.

[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] D. Owaki, T. Kano, K. Nagasawa, A. Tero and A. Ishiguro, "Simple Robot Suggests Physical Interlimb Communication Is Essential for Quadruped Walking", Journal of Royal Society of Interface, 2012 (DOI: 10.1098/rsif.2012.0669)
[2] T. Kano, T. Sato, R. Kobayashi, and A. Ishiguro, "Local Reflexive Mechanisms Essential for Snake's Scaffold-based Locomotion", Bioinspiration & Biomimetics, 2012 (DOI: 10. 1088/1748-3182/7/4/046008)
[3] T. Kano, Y. Watanabe, and A. Ishiguro, "Towards Realization of Multi-terrestrial Locomotion: Decentralized Control of Sheet-like Robot Based on Scaffold-exploitation Mechanism", Bioinspiration & Biomimetics, 2012 (DOI: 10. 1088/1748-3182/7/4/046012)

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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 have presented an FFT and a neural system 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 and exploitations of new neural devices proposing a neuromorphic quantum computation.

Research Activities in 2012：(1) By using high-order synapses for an inverse function delayed neural network, we theoretically obtained the parameter values that presented optimal solutions only for traveling salesman and quadratic assignment problems. Furthermore, we proposed a generalized energy function for scheduling problems and an inverse function delay-less model for high speed numerical calculation of artificial neural networks.
(2) We also proposed new analyses based on the relationship among a potential and active regions for nonlinear dynamics, in which bursting oscillations were analyzed and designed.
(3) We studied a possibility of superconducting plural bits realization in the quantum bits computation algorithm. We demonstrated successfully a 4-bit parallel multiplier using a carry look-ahead adder with niobium integrated circuits to improve the performance of high-speed operation for the single flux-quantum fast Fourier transform and designed an 8-bit parallel multiplier. A neural network using superconducting quantum interference devices was fabricated and successfully demonstrated.

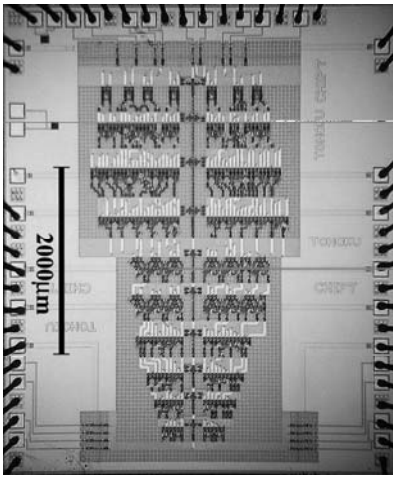

Figure 1 SFQ parallel multiplier

[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] Koji Nakajima, Shigeo Sato, and Yoshihiro Hayakawa, “Dynamic characteristics of a simple bursting neuron model,” Nonlinear Theory and Its Applications, IEICE, vol. 3, no. 3, pp. 436-456, (2012).
[2] Koji Nakajima, Shigeo Sato, and Yoshihiro Hayakawa, “Activation of Neural Networks and Nonlinear Analyses”、IEICE Fundamentals Review, Vol. 6, 2, pp. 1-11(2012)
[3] T. Onomi and K .Nakajima, “Design and Fabrication of an Improved Neural Circuit for Superconducting Neural Network Solving a Combinatorial Optimization Problem,” Proceedings of Superconducting SFQ VLSI Workshop SSV 2012, pp.63-66, Nagoya Japan, Dec. 2012.

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New Paradigm VLSI System Research Group

Realization of a New-Paradigm VLSI-Computing World

Takahiro Hanyu, Professor

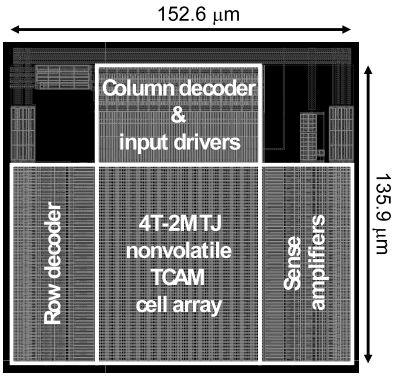

Fig. 1. MTJ/MOS-hybrid nonvolatile TCAM chip: Standby-power-free TCAM has been realized with the minimum transistor counts by merging logic, storage, and amplification functions.

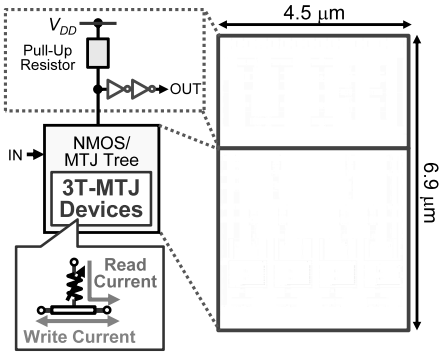

Fig. 2. Single-ended nonvolatile LUT circuit: A compact nonvolatile LUT circuit is realized by using 3-terminal MTJ (3T-MTJ) device where read and write current paths are separated.

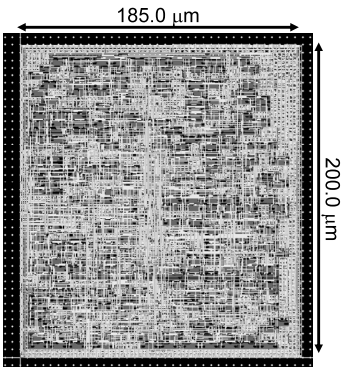

Fig. 3. MTJ/MOS-hybrid motion-vector prediction unit: The power supply for each processing element is controlled independently cycle by cycle, which achieves 75% leakage power reduction.

[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."

As this-year research results in nonvolatile-logic area, we have succeeded the fabrication of MTJ (Magnetic Tunnel Junction)-based ternary content-addressable memory (TCAM) chip (Fig.1), which has achieved zero-standby-power with minimum transistor counts. We have also designed a single-ended nonvolatile lookup table (LUT) circuit using 3-terminal MTJ devices (Fig.2), and demonstrated its compactness. Furthermore, we have also designed an MTJ/MOS-hybrid motion-vector prediction unit with cycle-based power gating (Fig.3), which achieved 75% leakage power reduction.

[Staff]

Professor : Takahiro Hanyu, Dr.
Assistant Professor : Matsumoto Atsushi, Dr.
Assistant Professor : Masanori Natsui, Dr.

[Profile]

Takahiro Hanyu received the B.E., M.E. and D.E. degrees in Electronic engineering from Tohoku University, Sendai, Japan, in 1984, 1986, 1989, respectively. He is currently a Professor in the Research Institute of Electrical Communication, Tohoku University. His general research interests include multiple-valued current-mode logic and its application to high performance and low-power arithmetic VLSIs.

[Papers]

[1] D. Suzuki, et al., "A 71%-Area-Reduced Six-input Nonvolatile Lookup-Table Circuit Using a Three-Terminal Magnetic-Tunnel-Junction-Based Single-Ended Structure," Japanese Journal of Applied Physics, Vol.52, No.4, pp.04CM04-1-04CM04-6, 2013.

[2] M. Natsui, et al, "Nonvolatile Logic-in-Memory Array Processor in 90nm MTJ/MOS Achieving 75% Leakage Reduction Using Cycle-Based Power Gating," IEEE Int. Solid-State Circuits Conf. (ISSCC) Dig. Tech. Papers, pp.194-195, 2013.

[3] S. Matsunaga, et al, "A 3.14 μm^2 4T-2MTJ-Cell Fully Parallel TCAM Based on Nonvolatile Logic-in-Memory Architecture," Symposium on VLSI Circuits Digest of Technical Papers, 6-2, pp. 44-45, 2012.

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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 research and development of practical technologies for IT based 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 planned 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 2012 the project attained (1) Proposal of the evaluation concept of 'wireless dependability' for wireless communication network, (2) Design and prototyping of the 60GHz beam-forming antenna for millimeter 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 2012, (1) From computer simulations, it was shown that 90 % of information can be available even when a half (50%) servers are lost or damaged, (2) High-speed data-transfer for urgent file backup was investigated by parallel-transfer storage devices and smart-routing network systems, (3) Highly functional programing frame-work that can access both established relational data-base and key-value store methods for cloud servers.

[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

[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 (Analog-to-Digital Converter/ Digital-to-Analog Converter): We have devised a current mode pipeline ADC, which is suitable for process miniaturization and low supply voltage.

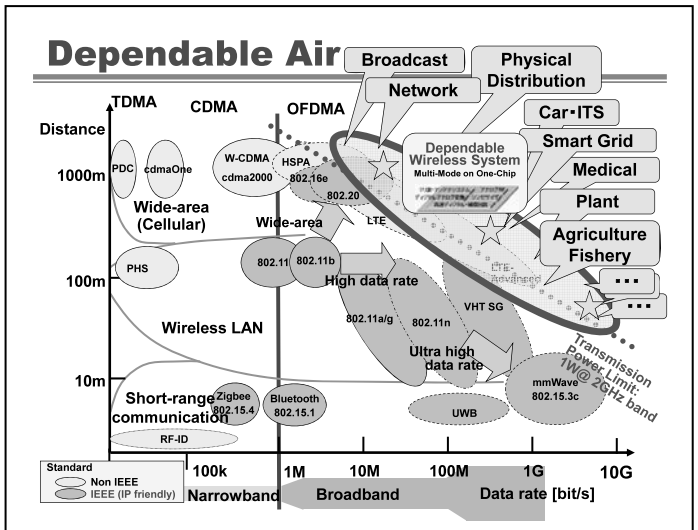

Fig. Dependable Air

[Staff]

Visiting Professor: Kazuo Tsubouchi, Ph.D

Visiting Professor: Tadashi Takagi, Ph.D

[Profile]

Kazuo Tsubouchi received the Ph.D. degree in Electronics Engineering from Nagoya University in 1974. In 1974, he joined the Research Institute of Electrical Communication, Tohoku University. In 1982, he spent at Purdue University as a Visiting Associate Professor. From 1993 to 2010, he has been a professor of RIEC, Tohoku University. From 2002 to 2010, he has been the director of IT-21 Center. He is currently a visiting professor. He received the "Minister of Education, Culture, Sports, Science and Technology, Award" in the Award for Persons of Merit in Industry-Academia-Government Collaboration in FY2007, et al. He is a member of the IEEE, the IEICE, the Physical Society of Japan, the Japan Society of Applied Physics, and the Institute of Electrical Engineers of Japan.

Tadashi Takagi received the B.S. degree in physics from Tokyo Institute of Technology, Tokyo, Japan and Ph.D. degree in electronic engineering from Shizuoka University, Shizuoka, Japan, 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, Tohoku University. He is currently a visiting professor. He is a fellow of IEICE and a senior member of the IEEE.

[Papers]

[1] Y. Suzuki et al., "60 GHz Band 2x4 Dipole Array Antenna Using Multi Stacked Organic Substrates Structure," The International Symposium on Antennas and Propagation (ISAP2012), Oct. 2012.
[2] T. Ta et al., "A Si-CMOS 5-bit Baseband Phase Shifter Using Fixed Gain Amplifier Matrix," European Microwave Conference 2012 (EuMC2012), Oct. 2012.
[3] T. Takagi et al., "A Novel Planer Type Broadband CMOS On-chip Balun with Relative Bandwidth of 158%," The 2012 Asia-Pacific Microwave Conference (APMC2012), Dec. 2012.

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Management Office for Health and Safety

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 Health and Safety

The Management Office for Health and Safety is established to maintain the health and safety 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 Health and Safety provides support for health and safety 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 Health and Safety

For the actual management of health and safety at the office, the Health and Safety Committee first presents the basic policies of safety management at the institute, and the Management Office for Health and Safety 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 Health and Safety 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 health and safety. 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 health and safety management system and working environment within the institute
- ○ Holding first-aid training course
- ○ Investigation of laws related to health and safety and collection of information regarding health and safety management
- ○ Providing advice and information to health and safety personnel in each department

[Staff]

Manager: Michio Niwano, Professor

Deputy Manager: Yoichi Uehara, Professor

Assistant Professor: Nobuyuki Sato,

Technical Official: Maho Abe,　Clerk: Ayako Chiba,

Flexible Information System Research Center

Development of Flexible Information Systems and Management of Network

[Research Target and Activities]

The present information systems such as computers are inflexible systems, because their purpose is predefined and they provide only the fixed procedures and functions. On the other hand the flexible information system can perform the advanced information processing with respect to the human intention and situation of its environment.

Our goal is to investigate the design principles of flexible information system through the theories and the experiments, and establish their system construction methodology. Moreover, we also study the flexible distributed systems to use/reuse, organize, and manage scientific information. Developing practical applications of above results to the real network in RIEC, we confirm effectiveness of our methods. To achieve the above goal, this year we have conducted the following research themes:

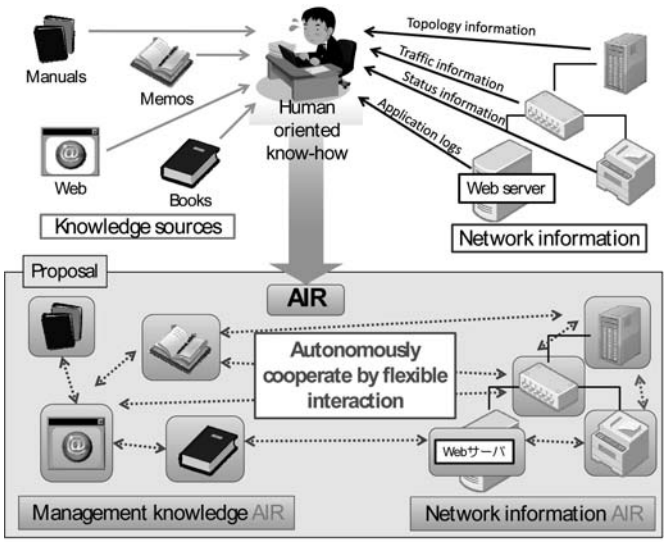


Fig.1 Knowledge based Network Management System.

(1) development of distributed and scalable authentication method for large scale overlay network,
(2) development of an agent based network management system (Fig.1) and
(3) flexible computing mechanism in biological system.

[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
Research Fellow: Johan Sveholm Dr.
Technical Support Member: Midori Suzuki, Sachiko Nagase, Yuki Ohashi
(3) Regular Staff
Associate Professor: Gen Kitagata, Dr.
Assistant Professor: Kazuto Sasai, Dr.
Technical Official: Masahiko Sato
Research Fellow: Johan Sveholm, Dr.
Technical Support Member: Midori Suzuki, Sachiko Nagase, Yuki Ohashi

[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.

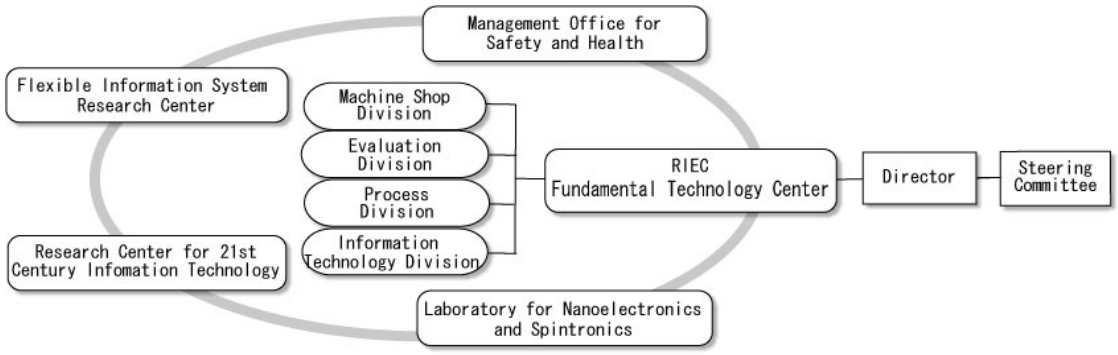
[Papers]

1. Kazuto Sasai, Gen Kitagata, Tetsuo Kinoshita, "Fault Resolution Support based on Activated Knowledge and Information," Proc. of The 25th International Conference on Industrial, Engineering & Other Applications of Applied Intelligent Systems, pp.586-595, 2012.06.

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 167, following requests from researchers. About 10 % of the requests were from the outside of the institute.

2. Evaluation Division

17 laboratories utilized evaluation and measurement apparatuses for shared usage (the utilization time was 3435 hours in total). Glass processing products of 9 were supplied. Several services relating to supply of cryogenic liquids were provided. 9 laboratories used the project clean room (PCR), a clean room for shared usage, which is operated by this division.

3. Process Division

This division supplied electron-beam lithographic products of 145, in cooperation with the cooperation section of the office, Laboratory for Nanoelectronics and Spintronics. Technical supports were provided for operating and maintain clean rooms of Laboratory for Nanoelectronics and Spintronics. Customized optical elements were supplied to 2 laboratories.

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 Research 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 : Fumitaka Saito, Katsumi Sagae, Koichi Shoji, Tamotsu Suenaga, Maho Abe, Keisuke Sato, Kento Abe, Masahiko Sato, Yuko Maruyama, Yurika Iwami, Choichi Takyu, Yasuo Wagatsuma, Shigeto Agatsuma, Hiroshi Watanabe, Munetomo Sugawara, Toshiyasu Meguro, Setsuko Odagiri, Midori Suzuki, Shoko Nagase, Yuki Ohashi

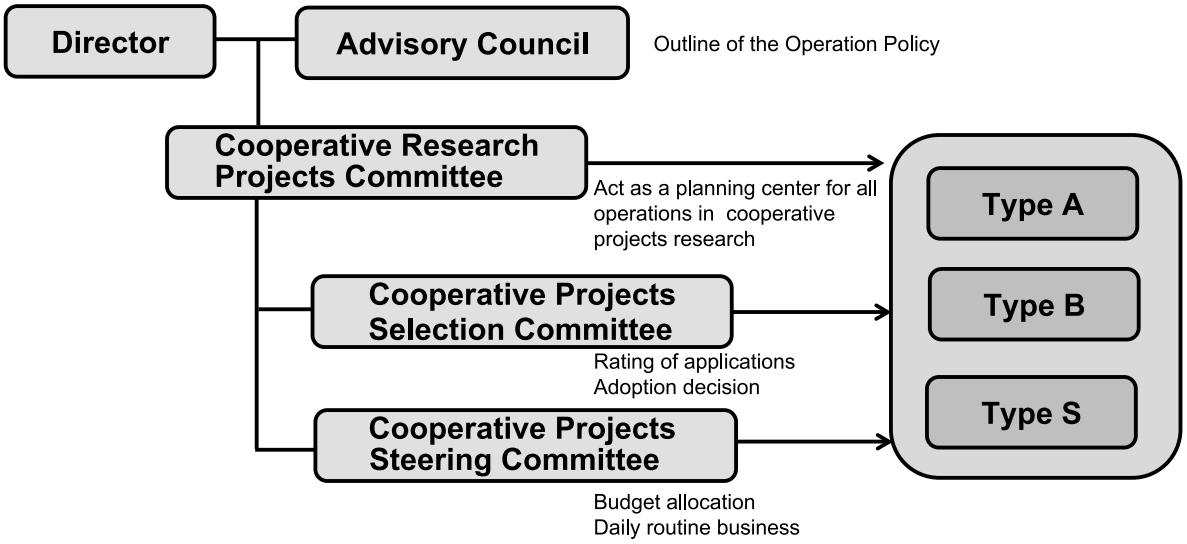
4. Nation-wide Cooperative Research Projects

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 Judging 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 2012

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H22／A02 Formation and Valency Control of Ge-based Quantum Dots and Their Application to Nanoscale Functional Memories	**Seiichi Miyazaki** Graduate School of Engineering, Nagoya University	Michio Niwano
H22／A03 Computational Materials Design and Device Applications of Magneto-electric and Magneto-elastic Effects	**Tatsuki Oda** College of Science and Engineering, Kanazawa University	Masafumi Shirai
H22／A04 Study on High-Efficiency Switching-Mode Power Amplifier with InGaAs HEMTs	**Yohtaro Umeda** Tokyo University of Science Faculty of Science and Technology Electrical Engineering	Tetsuya Suemitsu
H22／A05 Broadband light generation and detection using electron tunneling	**Yoichi Uehara** Research Institute of Electrical Communication, Tohoku University	Yoichi Uehara
H22／A06 Research of spintronics devices with negative spin-polarization materials	**Masakiyo Tsunoda** Graduate School of Engineering, Tohoku University	Masafumi Shirai
H22／A07 Chemical synthesis of pure Fe nanoparticle assembly with high saturation magnetization and its soft magnetic properties	**Migaku Takahashi** Graduate School of Engineering, Tohoku University	Kazushi Ishiyama
H22／A08 Research on personal acoustic telepresence system	**Tatsuya Hirahara** Toyama Prefectual University	Yôiti Suzuki
H22／A09 Multimodal speech communication system based on human perceptual property	**Akihiro Tanaka** Waseda Institute for Advanced Study	Shuichi Sakamoto

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H22／A11 Development of universal training system using acoustic virtual reality technique	Makoto Oh-uchi Faculty of General Management, Tohoku Fukushi University	Yôiti Suzuki
H22／A12 Directivity control on frequency domain binaural model	Yoshifumi Chisaki Kumamoto University	Yôiti Suzuki
H22／A13 Study of Brainware Systems	Toshiyuki Kanoh NEC Corporation	Koji Nakajima
H22／A14 Fundamental Study to Obtain Understanding on Working Network to Fully Make Use of the Knowledge	Ryuji Igarashi Administration Department Faculty of Engineering and Resource Science, Akita University	Gen Kitagata
H23／A02 Optoelectronic devices using carbon-based nanomaterials	Takashi Uchino Tohoku Institute of Technology	Taiich Otsuji
H23／A03 Development of the fabrication technique for atomically-controlled Si- and Ge-MIS structures and the evaluation technique of their interfaces	Hiroshi Okamoto Hirosaki University	Michio Niwano
H23／A04 Highly-Strained and Atomically-Controlled Heterostructure Formation of Group-IV Semiconductors and Nanodevice Application	Masao Sakuraba Research Institute of Electrical Communication, Tohoku University	Michio Niwano
H23／A06 Heterogeneous Network Roaming Technology for Dependable Air	Noriharu Suematsu Research Institute of Electrical Communication, Tohoku University	Noriharu Suematsu
H23／A08 Signal transduction of the artificial neuronal network	Haruyuki Kamiya Hokkaido University Graduate School of Medicine School of Medicine	Michio Niwano

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H23／A09 Development of flexible printable organic/inorganic heterojunction solar cells	**Fumihiko Hirose** Faculty of Egineering, Yamagata University	Michio Niwano
H23／A10 Development of magnetic devices using thin film element with inchlined stripe magnetic domain and its applications	**Hiroaki Kikuchi** Iwate University	Kazushi Ishiyama
H23／A11 Research on Infrastructure System for Cyber-Physical Integrated Society	**Hiroshi Shigeno** Science and Technology, Keio Univercity	Gen Kitagata
H23／A12 Two-dimensional sound localization based on a monaural input signal	**Masashi Itoh** Tohoku Institute of Technology	Yôiti Suzuki
H24／A01 Development of ultra-bright entangled photon sources	**Ryousuke shimizu** The University of Electro-Communications	Keiichi Edamatsu
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／A05 Development of Highly Sensitive Sensors Using Surface Plasmons Excited on Periodic Structure	**Hiroyuki Odagawa** Kumamoto National College of Technology	Yasuo Cho

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
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℃	Junichi Kushibiki Graduate School of Engineering, Tohoku University	Yasuo Cho
H24／A08 Study on Electron and Nuclear spins in semiconductor nanostructures	Yuzo Ohno Graduate School of Pure and Applied Sciences, University of Tsukuba	Hideo Ohno
H24／A09 Spintrosensor Development and its Medical-Bio Application	Seiji Sahashi Graduate School of Engineering, Tohoku University	Kazushi Ishiyama
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, Tohoku University	Michio Niwano
H24／A14 3D spatial perception and spatio-temporal multisensory integration	Yôiti Suzuki Research Institute of Electrical Communication, Tohoku University	Yôiti Suzuki

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 Nitech InformationTechnology Center , Nagoya Institute of Technology	Tetsuo Kinoshita
H22／B02 Application and Basic Study of Fine Particle Plasmas	Tetsu Mieno Faculty of Science, Shizuoka University	Michio Niwano
H22／B05 New Principle Nano Devices Based on Nano-Scale Control of Fluctuation and Electron Correlations	Shintaro Nomura Graduate School of Pure and Applied Sciences, University of Tsukuba	Hideo Ohno
H22／B06 Research of large-format quantum detector arrays with High-Q microwave superconducting resonators	Toshiyuki Miyazaki RIKEN	Shigeo Sato
H22／B07 Challenge and Perspective for Millimeter Wave Applications	Yohei Ishikawa Research Institute for Sustainable Humanosphere, Kyoto University	Noriharu Suematsu
H22／B08 Investigation of Bio-inspired Information Theory and its Technological Application	Daisuke Uragami Tokyo University of Technology	Kazuto Sasai
H22／B09 Study on visual information of material surface properties	Katsunori Okajima Yokohama National University	Ichiro Kuriki
H22／B10 Program Verification with Mathematical Logic	Masahiko Sato Kyoto University	Yoshihito Toyama
H22／B11 Development and Application of Synthetic Aperture Radar System for Civilian Use	Atsushi Mase Art, Science and Technology Center for Cooperative Research, Kyushu University	Hiroshi Yasaka

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H23／B01 Research for MEMS / high-frequency devices with nano-structured magnetic materials for advanced communications equipments	Makoto Sonehara Dept. of Electrical and Electronic Engineering, Faculty of Engineering, Shinshu University	Kazushi Ishiyama
H23／B02 Research on the new concept large scale memory and its system with integration of nano materials on silicon technology	Heiji Watanabe Graduate School of Engineering, Osaka University	Hideo Ohno
H23／B03 Research on nano semiconductor materials and nano structured devices required for future electronic systems	Kikuo Yamabe Graduate School of Pure and Applied Sciences, Tsukuba University	Hideo Ohno
H23／B04 New Technologies for Reducing Iron Loss of Electrical Steels	Kazushi Ishiyama Research Institute of Electrical Communication, Tohoku University	Kazushi Ishiyama
H23／B05 Study of functional piezoelectric materials and applications to advanced communication devices	Shin-ichiro Umemura Graduate School of Engineering Tohoku University	Yôiti Suzuki
H23／B06 Ultrafast Coherent Lightwave Control Technologies for Ultimate Communication and Measurement Systems	Hidemi Tsuchida National Institute of Advanced Industrial Science and Technology	Masataka Nakazawa
H23／B08 Passive/Active Circuit Technologies and Their Applications for Next Generation RFIC	Toshio Ishizaki Faculty of Science And Technology, Ryokoku University	Noriharu Suematsu
H23／B09 Multisensory integration involving self-body motion	Kenzo Sakurai Faculty of Liberal Arts, Tohoku Gakuin University	Yôiti Suzuki
H23／B11 Foundation of Dependable Cloud System with a Highly Reliable Programming Language System	Kazuhiko Kato Graduate School of Systems and Information Engineering, Tsukuba University	Atsushi Ohori

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
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／B04 Interpersonal Communications in a Media Space	Yoshifumi Kitamura Research Institute of Electrical Communication, Tohoku University	Yoshifumi Kitamura
H24／B05 Entertainment Computing for Creative Rejuvenation	Yoshifumi Kitamura Research Institute of Electrical Communication, Tohoku University	Yoshifumi Kitamura
H24／B06 Federation of Human Interface Research in 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
H24／B09 Control of Large Degree-of -Freedom System Inspired by Animal Locomotion	Ryo Kobayashi Graduate School of Science, Hiroshima University	Akio Ishiguro

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 Engineering Tohoku University	Satoshi Shioiri
H24／B12 Evolution of elementary technologies of high performance Computing for national security needs	Shin-ichi Mineo Research Organization for Information Science & Technology	Takahiro Hanyu
H24／B13 Studies on enrichment technologies for digital contents	Akira Nishimura Tokyo University of Information Sciences	Yôiti Suzuki
H23／S01 Development of essential technologies directed to systematization of superhivision	Hidenori Mimura Shizuoka University Research Institute of Electronics	Yôiti Suzuki
H23／S02 Spintronics International Alliance	Kohei Itoh Keio University Science and Technology	Hideo Ohno
H23／S03 Collaborative Research on Nano-electronics	Tetsuya Osaka Waseda Univ. Institute for Nanoscience & Nanotechnology	Michio Niwano
H24／S01 Empathic Computing System based on an innovative new concept associated with human functions	Masayuki Numao The Institute of Scientific and Industrial Research, Osaka University	Masafumi Shirai

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 Computer and Brain Functions	Nov.15-16, 2012
50	Tohoku – Harvard Joint Workshop New Directions in Materials for Nanoelectronics, 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

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. Hirohito Yamada
Manager	Associate Prof. Yasuo Ohtera

Acoustic Engineering	
Chair	Prof. Akinori Ito
Manager	Associate Prof. Shuichi Sakamoto

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. Noriyasu Homma

Information-biotronics	
Chair	Prof. Michio Niwano
Manager	Prof. Tatsuo Yoshinobu

Spinics	
Chair	Prof. Masashi Sahashi
Manager	Associate Prof. Shuichiro Hashi
Manager	Assistant Prof. Tetsuya Takura

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

Ultrasonic Electronics	
Chair	Prof. Hiroshi Kanai
Manager	Associate Prof. Hideyuki Hasegawa

Brainware	
Chair	Prof. Koji Nakajima
Manager	Prof. Shigeo Sato

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. Hideo Ohno
Manager	Associate Prof. Yasuo Kimura

Advenced Information Communication Engineering	
Chair	Prof. Tetsuo Kinoshita
Manager	Prof. Takuo Suganuma

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 (U.S.A)

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

1	Advanced Robotics
2	Applied Acoustics
3	Higher-order and symbolic computation
4	IEICE Electronics Express
5	IEICE Transaction On Electronics
6	Interdisciplinary Information Science
7	International Journal of Artificial Intelligence, Neural Networks, and Complex Problem Solving Technologies
8	International Journal of Energy, Information and Communications
9	International Journal of Information Sciences and Computer Engineering (IJISCE)
10	International Journal of Wireless Information Networks
11	Journal of Ambient Intelligence and Humanized Computing
12	Journal of Magnetics, Korean Magnetics Society
13	Journal of SPIN
14	JSAP-MRS Joint Symposia 2013 JJAP Special Issues
15	Nature Communications

16	Neural Networks
17	Nonlinear Theory and Its Applications, IEICE
18	NPG Asia Materials
19	Optical Fiber Technology
20	Optics Communications
21	Proceedings Special Issue on Emerging Graphene-Based Electronic and Photonic Devices, Circuits and Systems
22	The Journal of Computer Animation and Virtual Worlds

Recent international conferences programmed by a staff in RIEC:

1	2012 Spintronics Workshop on LSI
2	2013 Conference on Lasers and Electro-Optics(CLEO2013)
3	2014 Asia-Pacific Microwave Conference (APMC2014)
4	2014 Topical meeting on Microwave Photonics Conference (MWP2014)
5	3DUI: IEEE Symposium on 3D User Interfaces
6	3rd CSIS International Symposium on Spintronics-based VLSIs and 11th RIEC International Workshop on Spintronics
7	4th International Workshop on Spin Caloritronics
8	5th Int. Symp. of SiGe & Ge: Materials, Processing, and Device Symp.
9	5th International Conference on Recent Progress in Graphene Research(RPGR2013)
10	6th Int. Workshop on New Group ⅣSemiconductor Nanoelectronics
11	7th International Conference on the Physics and Applications of Spin Related Phenomena in Semiconductors (PASPS-VII)
12	7th Terahertz Days/GDR-I Workshop
13	8th Int. Conf. on Silicon Epitaxy and Heterostructures
14	17th International Conference on Molecular Beam Epitaxy (MBE2012)
15	26th International Microprocesses and Nanotechnology Conference(MNC2013)
16	ACM SIGGRAPH Asia
17	ACM SIGGRAPH Asia 2013: The 6th SIGGRAPH Conference and Exhibition on Computer Graphics and Interactive Techniques in Asia 2013
18	ACSIN: 12th International Conference on Atomically Controlled Surfaces, Interfaces and Nanostructures
19	APCHI 2012: 10th Asia Pacific Conference on Computer Human Interaction
20	APMC: Asia-Pacific Microwave Conference
21	Asia-Pacific Conference on Vision (APCV) 2012
22	Asia-Pacific Conference on Vision (APCV) 2014
23	AWAD: Asia-Pacific Workshop on Fundamentals and Applications of Advanced Semiconductor Devices
24	CIMTEC2014: 13th International Ceramics Congress, 6th Forum on New Materials, and 5th International Conference Novel Functional Carbon Nanomaterials
25	EDISON: 18th International Conference on Electron Dynamics in Semiconductors, Optoelectronics and Nanostructures
26	EGVE: Eurographics Workshop on Virtual Environment
27	ESSDERC: European Solid-State Device Research Conference
28	European Conference on Optical Communication (ECOC)
29	GSMM(Global Symposium on Millimeter wave) 2013
30	GSMM: 6th Global Symposium on Milli-Meter Waves
31	Haskell Symposium
32	ICAT 2013: International Conference on Artificial Reality and Tele-existence

33	ICAT: International Conference on Artificial Reality and Tele-existence
34	ICOOPMA: International Conference on Optical, Optoelectronic and Photonic Materials and Applications
35	IEDM: International Electron Device Meeting
36	IEEE International Symposium on Asynchronous Circuits and Systems
37	IEEE International Symposium on Multiple-Valued Logic
38	IFIP (International Federation for Information Processing) TC-13 (Human-Computer Interaction)
39	International Colour Vision Society (ICVS) 2015
40	International Conference of Magnetism (ICM)
41	International Multisensory Research Forum（IMRF）2013
42	International Quantum Electronics Conference (IQEC), Program Subcommittee Member for Quantum Information
43	International Symposium on Nonlinear Theory and Its Applications
44	ISCS: International Symposium on Compound Semiconductors
45	MMM/Intermag 2013, Chicago
46	OTST: Int. Conf. on Optical Terahertz Science and Technology
47	PIMRC (Personal, Indoor and Mobile Radio Communications) Symposium
48	SPIE International Conference on Defense, Security, and Sensing
49	SPIE Photonics West, Physics and Simulation of Optoelectronic Devices, Program Committee Member
50	The 10th International Conference on Distributed Computing and Internet Technologies (ICDCIT-2014)
51	The 16th International Conference on Network-Based Information Systems (NBiS-2013)
52	The 1st IEEE International Workshop on Consumer Devices and Systems held in conjunction with COMPSAC 2013
53	The 2013 IEEE/WIC/ACM Intern. Joint Conference on Web Intelligence and Intelligent Agent Technology (WI-IAT 2013)
54	The 20th International Conference on Neural Information Processing (ICONIP2013)
55	The 23th Intern.Conf.Industrial & Engineering Applications of Artif. Intell. & Exp. Systems (IEA/AIE-2013)
56	The 25th international Conference on indium Phosphide and Related Materials (IPRM2013)
57	The 2nd International Workshop on Smart Technologies for Energy, Information and Communication (STEIC2013)
58	The 9th RIEC International Workshop on Spintronics
59	The International Symposium on Multi-Agent Systems and Practical Applications (IMSPA2013)
60	The Magnetic Recording Conference 2013 (TMRC 2013)
61	Tohoku-Harvard Joint Workshop, New Directions in Materials for Nanoelectronics, Spintronics and Photonics (The 10th RIEC International Workshop on Spintronics)
62	TWHM: Topical Workshop on Heterostructure Microelectronics
63	VRST: ACM Symposium on Virtual Reality Software and Technology

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 Departments of Electrical Engineering, Communication Engineering, Electronics Engineering, and Information Engineering of the Faculty of Engineering. Since the journal also aims at publishing general research activities of the Institute and of the Departments 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

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. Since the launch in March 2011 to March 2012, four issues have been published. Every issue introduces special topics such as large scale projects and the establishment of the Research Organization of Electrical Communication (ROEC) ,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. 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,Land and Buildings,Budget

1.Faculty & Staff

as of May 1, 2013

Professors	Associate Professors	Assistant Professors	Research Fellows	Specially Appointed Professors	Administrative Staffs	Technical Staffs	Total
24	20	24	25	3	17	10	123

2.Researchers (FY2012)

Foreign Researcher		Cooperative Researchers of Private Company etc	JSPS Postdoctral Fellows	Contract Researchers	Contract Trainee	Total
Visiting Professors	Visiting Asociate Professors					
7	1	4	4	6	1	23

3.Students

as of May 1, 2013

	School of Engineering	Graduate School of Information Science	RIEC	Total
Undergraduate Students	67(1)	0	0	67(1)
Master Cource Students	76(8)	49(9)	0	125(17)
Doctor Cource Students	28(7)	10(7)	0	38(14)
Institute Research Student	0	0	5(4)	5(4)
Total	171(16)	59(16)	5(4)	235(36)

※（ ）Foreigner

4.Land and Building

Site：Katahira 2-1-1, Aoba-ku, Sendai,980-8577, Japan
Building ：Total building area 12,913 ㎡ Total floor area 28,776 ㎡

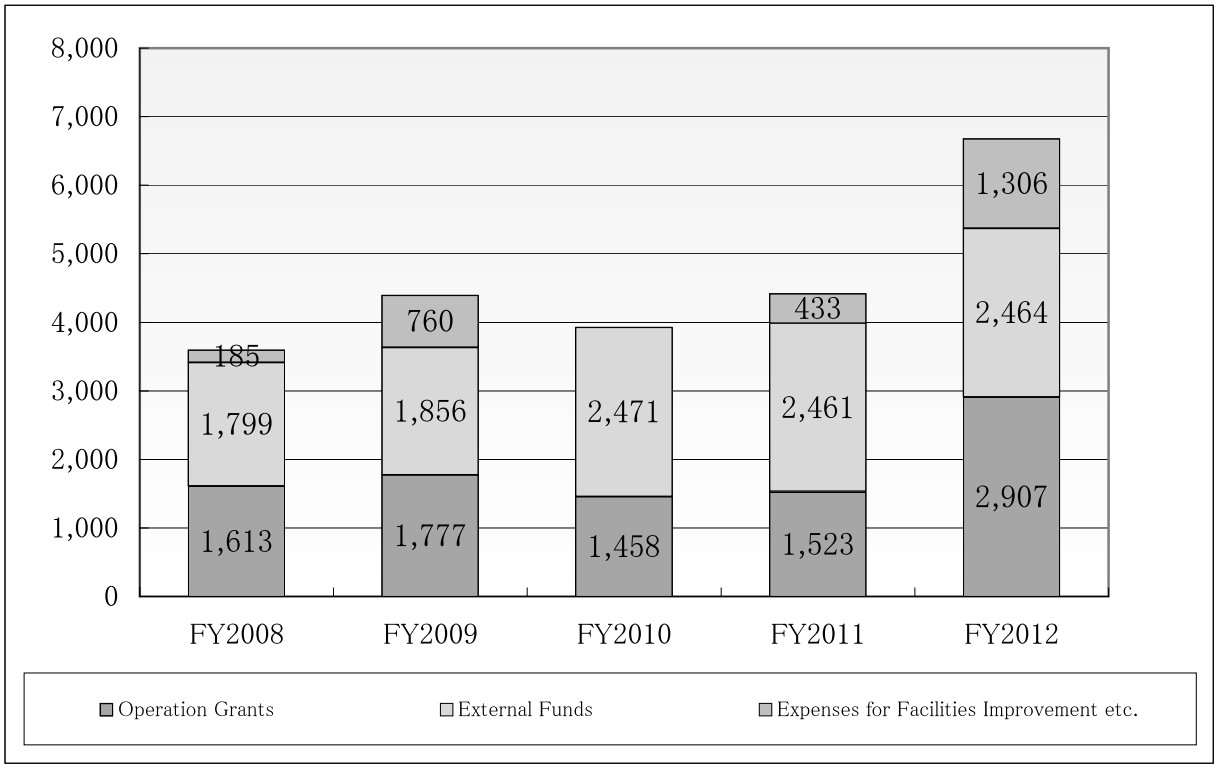
as of May 1, 2013

Name of Building	Structure	Year of Completion	Floor Area
Building No.1	Reinforced Concrete, 4 floors	Building-S：1962, 1963 Building-N：1959, 1960	7,772 ㎡
Building No.2	Reinforced Concrete, 4 floors	1962, 1963	7,085 ㎡
Laboratory for Nanoelectronics and Spintronics	Steel-frame, 5 floors	2004	7,375 ㎡
Laboratory for Brainware Systems	Reinforced Concrete, 1 floor	1967, 1968, 1972	525 ㎡
	Reinforced Concrete(partly steel-frame), 2 floors	1986	1,553 ㎡
	Steel-frame, 1 floor	1996	598 ㎡
	Light-weight steel-frame, 2 floors	1999	147 ㎡
Research Center for 21st Century Information Technology	Reinforced Concrete, 3 floors	1930	1,343 ㎡
	Steel-frame, 1 floor	2002	435 ㎡
Evaluation and Analysis Center	Reinforced Concrete, 2 floors	1981	790 ㎡
Helium Sub-Center	Reinforced Concrete(partly light-weight steel-frame), 1 floor	1972	166 ㎡
Machine Shop	Reinforced Concrete(partly light-weight steel-frame), 1 floor	1965, 1966, 1978	479 ㎡
Others			508 ㎡
Total			28,776 ㎡

5.Budget

Budget Shift

million yen



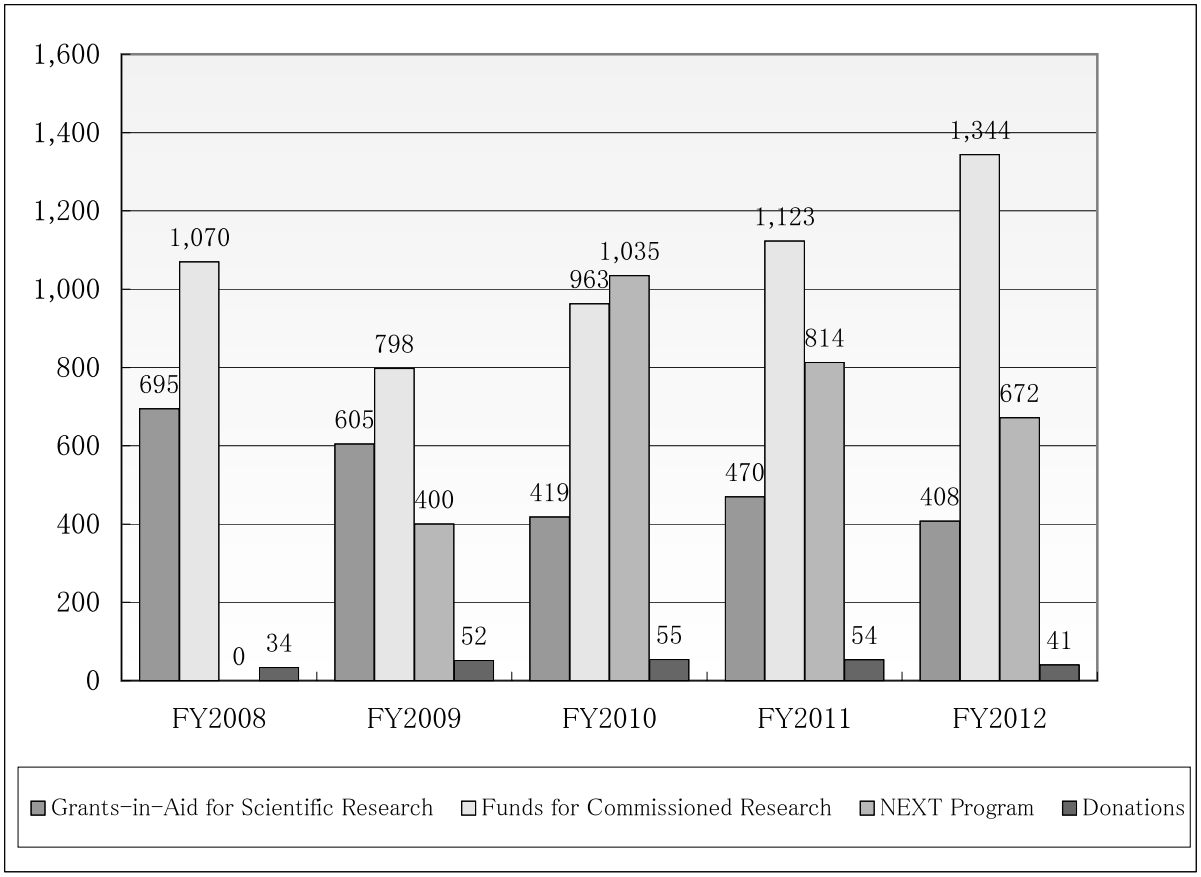
Budget Summary

thousand yen

Categories		FY2008	FY2009	FY2010	FY2011	FY2012
Operation Grants	Personnel Expenses	879,481	1,026,511	777,776	835,898	770,443
	Non-Personnel Expenses	733,735	750,364	680,411	687,253	2,136,780
Operation Grants Total		1,613,216	1,776,875	1,458,187	1,523,151	2,907,223
External Funds	Grants-in-Aid for Scientific Research	694,883	605,100	418,680	469,840	407,629
	Funds for Commissioned Research	1,069,832	798,053	962,712	1,122,944	1,344,071
	Funding Program for Next Generation World-Leading Researchers (NEXT Program)(JSPS)	0	400,440	1,034,827	813,777	671,668
	Donations	34,265	51,954	55,085	54,167	40,714
	Indirect Expenses	343,248	279,667	275,547	311,801	326,869
External Funds Total		1,798,980	1,855,547	2,471,304	2,460,728	2,464,082
Expenses for Reconstruction		0	0	0	432,607	4,993
Expenses for Facilities Improvement		185,000	760,000	0	0	1,300,530
Expenses for Facilities Improvement etc. Total		185,000	760,000	0	432,607	1,305,523
Total		3,597,196	4,392,422	3,929,491	4,416,486	6,676,828

External Funds

million yen



External Funds

thousand yen

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10. Concluding remarks

Thank you for reading the RIEC research activity report for the 2012 fiscal year.

Since university-affiliated research laboratories promote a wide range of studies based on the ideas of faculty members and provide education to students and the general public through their research, they play a complementary role to the laboratories of industries and govermnent institutions. It could also be said that the selection of members at faculty meetings also provides a framework that supports research based on free ideas. On the other hand, there is a need for constant scrutiny and verification regarding whether the research activities fully address the needs of society, or whether the results justify the degree of freedom given to researchers.

As mentioned in the introduction, the RIEC's field — i.e., the science and technology of information communication and communication itself — is growing in importance as a key part of the infrastructure of modern society. We must respond to the demand for technology that can be used safely and securely even in the event of a large-scale natural disaster, and can outperform current communications technology in terms of speed, capacity and energy savings. At the same time, we also hope to open up a new paradigm by implementing information processing and communications in a fundamentally different way that contributes to deeper mutual communication in the society. Although these two goals are closely related, the latter requires research into new and uncharted territory, where breakthroughs need to be made by conducting high-quality research based on free thinking — just the sort of research one would expect of a research facility tied to a university.

To promote multidisciplinary research that meets the demands of society, it is essential to have the right systems, the right scale, the right people, and the right environment. Having been certified by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) as a center for collaborative research in information science and technology, our future prospects depend on our being able to carry on with our usual

research while contributing to community development by systematically promoting joint research projects with outside researchers. Similarly, it is also essential that our cooperation relationships with Tohoku University's other Schools covering electrical and electronic engineering. As for the environment, a new building will be built to the north of Building 2 at the RIEC. Being able to carry out research together with many others in a new and enhanced environment is a great pleasure. On the other hand, the budget subsidies that are the basic expenses of university have been decreasing year on year, and even the RIEC has shrunk by 10 faculty members over the last ten years. To further develop the research being carried out here while maintaining an appropriate scale, it is essential that we secure funding by such means as making our priorities clearer and proposing special expenses that will allow us to request funding from MEXT and increasing the funding associated with faculty members. It is no exaggeration to say that we need to manage our organization than ever before.

In the external environment as described above, we are determined to continue to contribute to the development of communication. This report describing the RIEC's activities provides an important window into our activities, not only for us but also for those people outside our organization. We are deeply grateful for your suggestions, encouragement and frank comments, which provide us with essential guidelines for the future path of the RIEC.

May 1, 2013

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