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Annual Report 2016

Research Institute of Electrical Communication Tohoku University

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Research Institute of Electrical Communication
Tohoku University

Annual report of Research Institute of Electrical Communication 2016

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1. Introduction

Ever since the RIEC was established in 1935 based on the research of cutting-edge technologies such as Yagi-Uda antennas and magnetrons, a succession of pioneering achievements from the institute have laid the foundations of information science and communications technology. Today, the institute continues to play a world-leading role. This spirit of the RIEC was summed up 32 years ago in the words of then institute director Junichi Nishizawa, spoken at the institute's 50th anniversary celebration: "Study in research areas must begin while they still have no name. This spirit shall form the foundation of the Research Institute of Electrical Communication and the Electrical Engineering Group, Tohoku University." Building on this tradition, we will continue working to lead the world in the advancement and evolution of science and technology to realize new ways of communication that enrich people's lives.

The environment in which Tohoku University and the RIEC operate is constantly changing. The current fiscal year marks the second year of Japan's Fifth Science and Technology Basic Plan, which aims to realize a cycle of innovation toward a super-smart society. The plan sets out policies for strengthening the fundamental technologies that will support this, including cyber security, the "Internet of things," big data, artificial intelligence, and devices. It goes without saying that these research fields fall under the RIEC's scope of expertise and that the institute must play a leading role in furthering them. Meanwhile, the current fiscal year is also the second year of the Third Mid-term Planning Period for National Universities. Although operating grants have been reduced, reflecting Japan's fiscal circumstances, we are living in a time when universities are expected to form the nucleus of innovation. In order to meet these expectations, the RIEC must work to develop the communications technologies of the future, covering every aspect from fundamental technologies to application.

Since 2004, the institute's organizational structure has been organized into three units: four research divisions (Information Devices Division, Broadband Engineering Division, Human Information Systems Division, and Systems & Software Division), two laboratories (Laboratory for Nanoelectronics and

Spintronics, and Laboratory for Brainware Systems), and the Research Center for 21st Century Information Technology. These units are engaged in research aimed at achieving fruition over different time scales (Research Divisions: 20 years, Laboratories: 10 years, Research Center: 5 years). In addition, we collaborate closely with Tohoku University's graduate schools in subjects relating to electrical engineering (School of Engineering, Graduate School of Information Sciences, and Graduate School of Biomedical Engineering) in order to cover a wide range of cutting-edge research fields and foster the development of outstanding researchers and engineers.

The RIEC has also been certified by the Ministry of Education, Culture, Sports, Science and Technology as a Joint Usage/Research Center for collaborative research in information science and technology. The current fiscal year marks the second year of the program's second term. As management expenses grants decrease, our role in advancing the information and communication community—both in Japan and overseas—will become increasingly important. To this end, we are collaborating on joint research projects with external researchers and engineers from industry, government, and academia in a systematic manner.

Today, information and communication technology are an essential part of the social infrastructure. We must therefore realize faster, higher-capacity telecommunications with greater energy efficiency performance, while the experience of the Great East Japan Earthquake of 2011 reemphasized the importance of ensuring that our social infrastructure has a high resilience to disaster. We are expected to contribute to a new paradigm of information processing and communication methods that interconnect people in a fundamentally different way. Developed by the RIEC over more than 20 years, Brainware has become increasingly important with current trends in artificial intelligence (AI) research. We will continue to address these social needs by fully leveraging our strengths as a university-affiliated research center. In doing so, we hope to forge the path to a new world of communication, and through these efforts continue to promote education going forward.

To contribute to the improvement of our research activities and support future developments, we publish this Annual Report every year to make our

activities relating to research, education, and social contribution widely available for public scrutiny. This edition contains reports on a range of activities, including the research conducted by each of our departments and laboratories, collaborative research projects, international activities, social contributions, the RIEC symposium, activities of the engineering research association, and RIEC lectures. The bibliography section also includes data on the various activities we have conducted over the last five years.

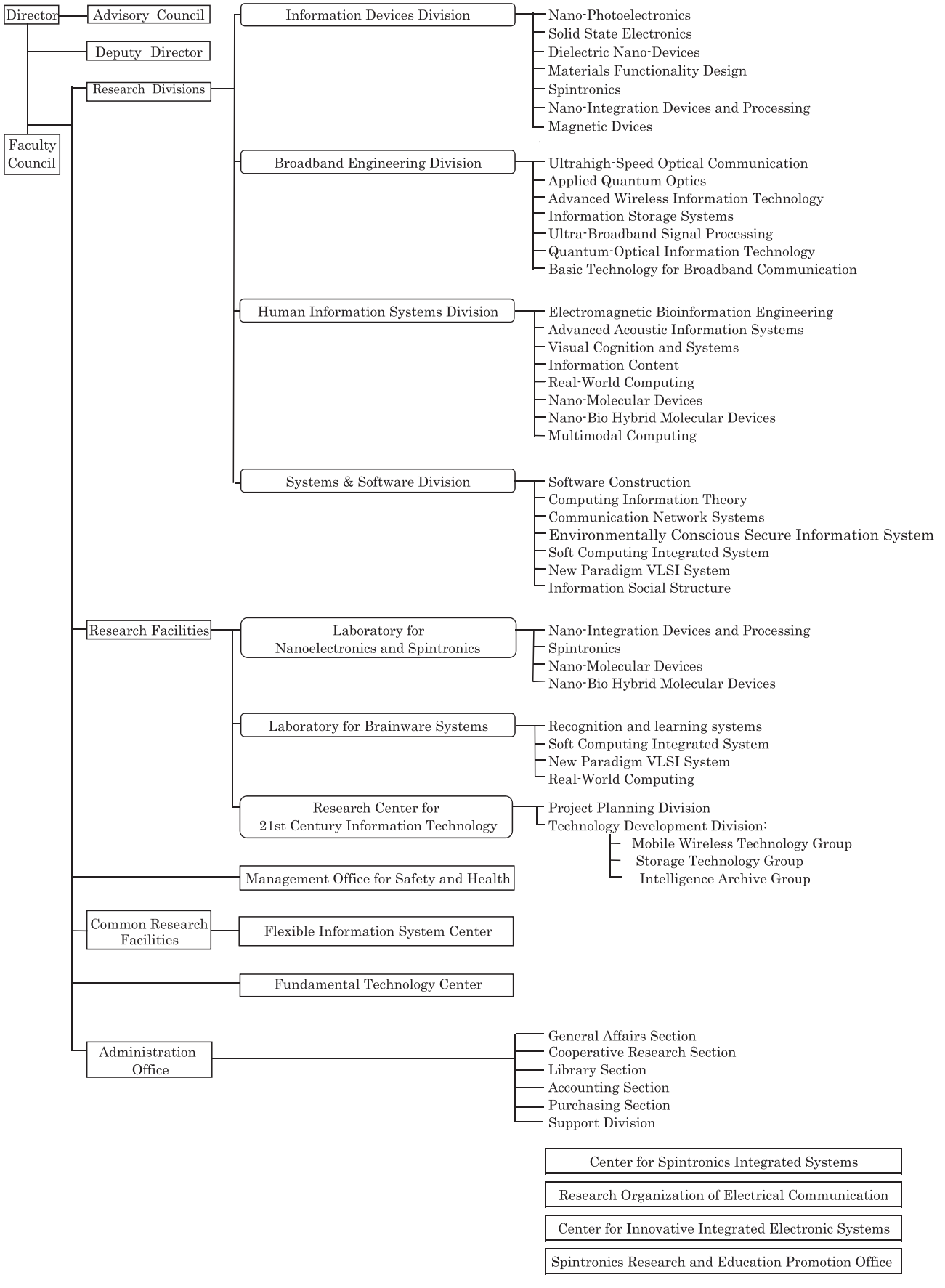
We welcome your frank opinions regarding our activities, and look forward to your continued guidance and support in the future.

May 8, 2017

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 7 sub-divisions. The research fields include nano-scale photoelectronic conversions, novel transport properties in low-dimensional systems, new dielectrics-based nano-devices for information storage, design of new materials having exotic functionalities, spintronics for next generation semiconductor devices and nano-integration devices and processing for neuron computing.

1. Nano-Photoelectronics
2. Solid State Electronics
3. Dielectric Nano-Devices
4. Materials Functionality Design
5. Spintronics
6. Nano-Integration Devices and Processing
7. Magnetic Devices (Visitor Section)

The research target and the summary of activities of each sub-division in 2016 are described in the following pages.

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. The summary of our achievements in 2016 is as follows. (1) We have been developing pump–probe STM emission spectroscopy, a novel spectroscopic method making it possible to explore material properties of surface nanostructures with atomic spatial and ps temporal resolution. This method was applied to VO_2. The tip was fixed over a nanometer scale gain of the monoclinic structure phase (M–phase) of VO_2. No STM light is emitted from the M–phase domain as is described in Ref. [1]. However, STM light emission is observed in 30 ps after irradiation of the tip-sample gap of the STM with the pump light pulse, showing that the crystalline structure changes to the tetragonal structure phase. The optically induced phase transition time (30 ps) determined by the proposed method is consistent with reported values measured by macroscopic methods such as time resolved X ray diffraction. Thus we concluded that this method works as is expected. (2) Nanoscale-luminescence of a single-walled carbon nanotube (SWCNT) adsorbed on the alkanethiolate self-assembled monolayer (SAM) was investigated using STM-LE. The electronic structure of the individual SWCNT was measured by STS, which revealed the adsorption structure of SWCNT on the SAM. The STM-LE spectra obtained at the SWCNT show the exciton-induced luminescence in the visible light region. (3) Optical properties of individual silver nanoparticles (AgNPs) were studied using STM-LE. We utilized a drop-cast method to create a well-ordered two dimensional array of AgNP on Au(111). The STM-LE spectrum obtained from the 2D array of AgNP exhibits the luminescence peak appearing in the visible light region. The STM-LE mapping revealed the inhomogeneous luminescence of the AgNP when formed the 2D-assembled structures.

[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] J. Sakai, M. Kuwahara, M. Hotsuki, S. Katano, and Y. Uehara, "Selective Scanning Tunneling Microscope Light Emission from Rutile Phase of VO_2", *J. Phys.: Condens. Matter.*, **28**, 385002 (2016).

[2] S. Katano, M. Hotsuki, and Y. Uehara, "Creation and Luminescence of a Single Silver Nanoparticle on Si(111) Investigated by Scanning Tunneling Microscopy", *J. Phys. Chem. C*, **120**, 28575-28582 (2016).

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Solid State Electronics Laboratory

Paving a Way for Introducing SiC, Graphene, and 2DM into Si Technology

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

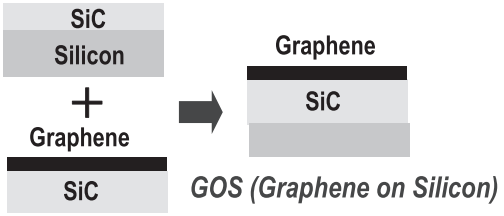
[Research Target and Activities]

Graphene is a 2D 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, which consists of 3C-SiC heteroepitaxy on Si and subsequent sublimation of surface Si atoms (graphene-on-Si, or GOS, technology). We are currently working on betterment of the GOS quality as well as on the development of graphene devices centered on RF field-effect transistors and optical devices.

In FY2016, we succeeded in growing extremely high quality epitaxial graphene on the C-face of SiC crystals for the first time. We developed operando analysis methods to characterize the device performance of 2D-material devices as well.

[Staff]

Professor : Maki Suemitsu, Dr.
Assistant Professor : Hirokazu Fukidome, Dr.
Visiting Professor : Hiroyuki Nagasawa, Dr.
Research Assistant : Goon-Ho Park, Dr.
Research Assistant : Fuminori Sasaki
Foreign Researcher: Gunasekaran Venugopal, Dr.
Technical Assistant: Misako Suzuki
Secretary: Kumi Namiiri



[Profile]

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

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

[Papers]

[1] M. Hasegawa, K. Tashima, M. Kotsugi, T. Ohkochi, M. Suemitsu, and H. Fukidome, “Inhomogeneous longitudinal distribution of Ni atoms on graphene induced by layer-number-dependent internal diffusion,” Applied Physics Letters, Vol. 109, pp. 111604-1 – 111604-5, 2016
[2] Ryota Suto, Gunasekaran Venugopal, Keiichiro Tashima, Naoka Nagamura, Koji Horiba, Maki Suemitsu, Masaharu Oshima, and Hirokazu Fukidome, “Observation of nanoscopic charge-transfer region at metal/MoS_2 interface,” Materials Research Express, Vol. 3, No. , pp. , 2016.
[3] Goon-Ho Park, Kwan-Soo Kim, Hirokazu Fukidome, Tetsuya Suemitsu, Taiichi Otsuji, Won-Ju Cho, and Maki Suemitsu, “High-performance self-aligned graphene transistors fabricated using contamination- and defect-free process,” Japanese Journal of Applied Physics, Vol. 55, No. 6S1, pp. 06GF11-1 - 06GF11-4, 2016.

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Dielectric Nano-Devices

Research on Dielectric Nano Science and Technology

Dielectric Nano-Devices Yasuo CHO, Professor
Dielectric Nanoscale Measurement Systems Kohei YAMASUE, Associate 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 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.

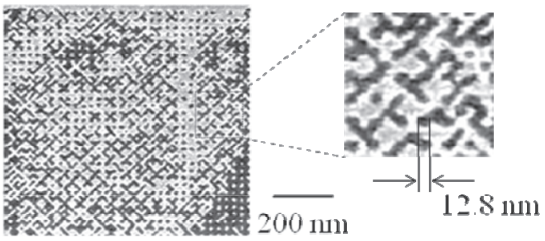

Fig.1 Digital bit data written on ferroelectric single crystal with the areal recording density of 4 Tbit/inch^2.

Major achievements of studies in 2016 are as follows: (1) SiO_2/SiC interfaces were evaluated using the local DLTS method based super-higher-order SNDM. In addition, SNDM successfully evaluated active dopant distribution and estimated effective diffusivity in phosphorus-implanted monocrystalline silicon solar cell (2) Dynamics of ferroelectric domain inversion in HfO_2 thin films was studied using SNDM for ferroelectric probe data storage technology (3) Scanning nonlinear dielectric potentiometry was applied to the atomic resolution imaging of graphene on C-face of SiC (4) We experimentally and numerically demonstrated that SNDM can image linear permittivity distribution.

[Staff]

Professor : Yasuo Cho, Ph.D. Associate Professor : Kohei Yamasue, Ph. D.
Assist. Professor: Yoshiomi Hiranaga, Ph.D. Specially-appointed Assist. Prof.: Yuji Yamagishi, Ph.D.

[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).

Kohei Yamasue received the Ph. D degree in engineering from Kyoto University in 2007. He then became a postdoctoral fellow in 2007 and an assistant professor in 2008 at Venture Business Laboratory, Kyoto University. In 2010, he joined Research Institute of Electrical Communication, Tohoku University, as an assistant professor and, in 2016, became an associate professor. His main interests include the development of atomic resolution scanning nonlinear dielectric potentiometry and its applications to the evaluation of the next-generation electronic materials and devices.

[Papers]

[1] N. Chinone and Y. Cho: "Visualization of gate-bias-induced carrier redistribution in SiC power DIMOSFET using scanning nonlinear dielectric microscopy", IEEE Trans. Electron Dev., Vol.63, pp. 3165-3170, 2016
[2] K. Yamasue *et al.*: "Graphene on C-terminated face of 4H-SiC observed by noncontact scanning nonlinear dielectric potentiometry", Jpn. J. Appl. Phys, Vol.55, pp.08NB02-1-5, 2016
[3] T. Aoki, Y. Hiranaga and Y. Cho: "High-density ferroelectric recording using a hard disk drive-type data storage system", J. Appl. Phys, Vol.119, pp.184101-1-8, 2016

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Materials Functionality Design

Computational Design of Functional Materials for Spintornics

Materials Functionality Design: Masafumi Shirai, Professor
Materials Science under Extreme Conditions: Kazutaka Abe, Associate Professor

[Research Target and Activities]

Our research targets are as follows: (1) theoretical analyses of quantum phenomena 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 2016 are as follows:

(1) Theoretical design for giant magnetoresistive (GMR) devices

We theoretically design non-magnetic materials for a spacer layer between two half-metallic Heusler-alloy layers in order to the GMR effect. We found that the Fermi-surface matching between the Heusler alloy and Ag_3Mg ordered alloy is better than Ag. Experimental results confirm the improved magnetoresistance for the device using the Ag_3Mg spacer [3].

(2) Metallization and superconductivity of polyhydrides

We investigated the possibility of scandium polyhydrides at high pressures, and found that metallic ScH_4 and ScH_6 are stabilized above 160 and 135 GPa, respectively. The estimated superconducting transition temperatures exceed 60 K, and especially that of ScH_6 around 285 GPa reaches 130 K.

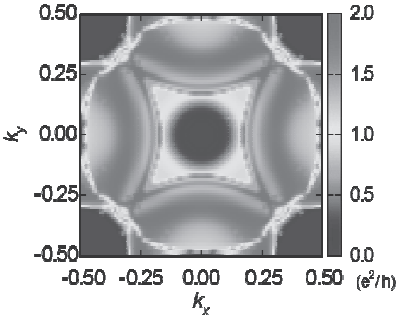


Fig. 1: The in-plane wavevector dependence of the majority-spin channel conductance calculated for the GMR device with Co_2(Fe,Mn)Si electrode and Ag_3Mg spacer [3].

[Staff]

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

[Profile]

Masafumi Shirai received the Doctor of Engineering degree from Osaka University in 1989. Since 2002, he has been a Professor at Tohoku University.

Kazutaka Abe received Doctor of Science degree from Osaka University in 1998. Since 2003, he has been at Tohoku University as a Research Associate, as an Assistant Professor, and currently as an Associate Professor.

[Papers]

[1] K. Moges, Y. Honda, H.-x. Liu, T. Uemura, M. Yamamoto, Y. Miura, and M. Shirai, "Enhanced half-metallicity of off-stoichiometric quaternary Heusler alloy Co_2(Mn,Fe)Si investigated through saturation magnetization and tunneling magnetoresistance," Phys. Rev. B, Vol. 93, Article no. 134403, pp. 1-15, 2016

[2] B. Hu, K. Moges, Y. Honda, H.-x. Liu, T. Uemura, M. Yamamoto, J. Inoue, and M. Shirai, "Temperature dependence of spin-dependent tunneling conductance of magnetic tunnel junctions with half-metallic Co_2MnSi electrodes," Phys. Rev. B, Vol. 94, Article no. 094428, pp. 1-15, 2016

[3] T. Kubota, Y. Ina, M. Tsujikawa, S. Morikawa, H. Narisawa, Z. Wen, M. Shirai, and K. Takanashi, "Current perpendicular-to-plane giant magnetoresistance devices using half-metallic $Co_2Fe_{0.4}Mn_{0.6}Si$ electrodes and a Ag-Mg spacer layer," J. Phys. D: Appl. Phys., Vol. 50, Article no. 014004, pp. 1-8, 2017

Spintronics

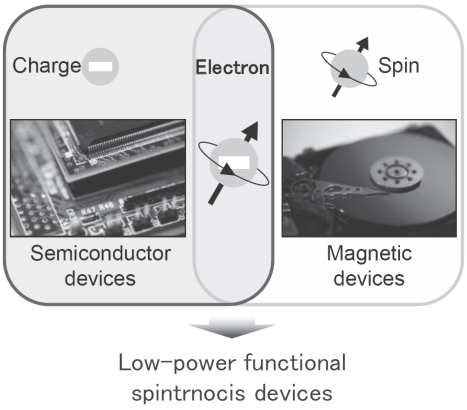
Advanced technology for spintronics-based devices

Functional Spintronics: Hideo Ohno, Professor
Nano-Spin Materials and Devices: Shunsuke Fukami, Associate Professor

[Research Target and Activities]

We aim to deepen the understanding of spin-related physics and to develop new functional materials and devices in which electron and its spin states are controlled. We are also working on research and development of advanced technology for spintronics-based devices and integrated circuits, which offers high-performance and low-power information and communication tecnologies.

The outcomes in the last fiscal year include (1) demonstration of sub-nanosecond magnetization switching by spin-orbit torque using a newly-developed device structure, (2) demonstration of associative memory operation by artificial neural network with analog spintronics devices (3) clarification of the effect of motional narrowing on the magnetization dynamics in thin films with interfacial anisotropy..



[Staff]

Professor: Hideo Ohno, Ph. D. Associate Professor: Shunsuke Fukami, Ph. D.
Assistant Professor: Shun Kanai, Ph. D., Justin Llandro, Ph. D.

[Profile]

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), Thomson Reuters Citation Laureates (2011), JSAP Outstanding Achievement Award (2011), IEEE David Sarnoff Award (2012), the 5th Isamu Akasaki Award (2015), Leo Esaki Prize (2016), and C&C Prize (2016). 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.

Shunsuke Fukami received Ph. D. degree from Nagoya University in 2012. He joined NEC Corp (2005). He moved to Tohoku University as an Assistant Professor (2011) and then as an Associate Professor (2015). He received the JSAP Paper Award (2012), the RIEC Award for Tohoku University Researchers (2013), the Funai Research Incentive Award (2014), the JSAP Young Scientist Presentation Award (2014), the Young Scientists' Prize of Science and Technology by the MEXT (2015), and the Harada Young Research Award (2015).

[Papers]

[1] S. Fukami, T. Anekawa, A. Ohkawara, C. Zhang, and H. Ohno, "A sub-ns three-terminal spin-orbit torque induced switching device," **2016** VLSI Symposia, T06-05 (2016).
[2] W A. Borders, H. Akima, S. Fukami, S, Moriya, S. Kurihara, Y. Horio, S. Sato, and H. Ohno, "Analogue spin.orbit torque device for artificial-neural-network-based associative memory operation," Appl. Phys. Ex., **10**, 013007 (2017).
[3] A. Okada, S. He, B. Gu, S. Kanai, A. Soumyanarayanan, S. T. Lim, M. Tran, M. Mori, S. Maekawa, F. Matsukura, H. Ohno, and C. Panagopoulos, "Magnetization dynamics and its scattering mechanism in thin CoFeB films with interfacial anisotropy," Proc. Nat. Acad. Sci. USA **114**, 3815 (2017).

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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) We have proposed a new quantum associative memory and the adiabatic change of Hamiltonian for association. Simulation results show that the proposed system has higher memory capacity. (2) Epitaxial growth of heavily C or B doped Si on Si(100) has been demonstrated by low-energy ECR plasma CVD without substrate heating. Moreover, it has been found that an epitaxial Si0.5Ge 0.5 alloy film grown without substrate heating show n-type properties with as high carrier mobility as 660 $cm^2 V^{-1} s^{-1}$.

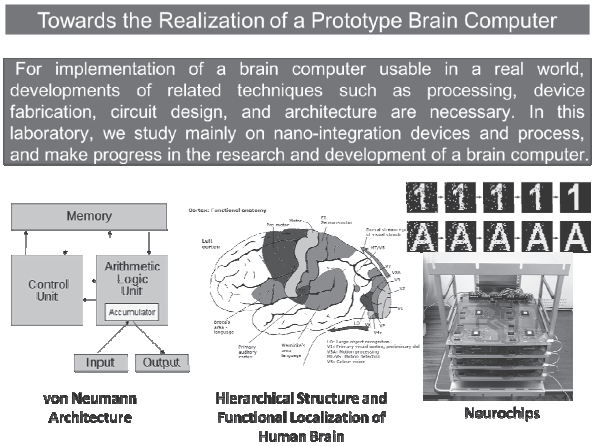
[Staff]

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

[Profile]

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

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.



Towards the Realization of a Prototype Brain Computer

[Papers]

[1] H. Akima, Y. Katayama, M. Sakuraba, K. Nakajima, J. Madrenas and S. Sato, "CMOS Majority Circuit with Large Fan-In", IEICE Trans. Electron, vol. E99c, no. 9, pp. 1056-1064, 2016.
[2] H. Yamamoto, S. Kubota, Y. Chida, M. Morita, S. Moriya, H. Akima, S. Sato, A. Hirano-Iwata, T. Tanii, and M. Niwano, "Size-dependent regulation of synchronized activity in living neuronal networks", Physical Review E, vol. 94, no. 1, pp. 012407, 2016.
[3] M. Sakuraba, H. Akima and S. Sato, "Epitaxy and In-Situ Doping of Group-IV Semiconductors by Low-Energy Plasma CVD for Quantum Heterointegration in Nanoelectronics" (Invited Paper), Abs. Energy Materials Nanotechnology (EMN) Meeting on Epitaxy, No.A19, pp.61-63, Budapest, Hungary, Sep. 4-8, 2016.

Broadband Engineering Division: Research Target and Results

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

(1) Advanced Wireless Information Technology

We are actively engaged in the research work on the dependable wireless information technologies for the next generation wireless systems, which include terrestrial / satellite communications. We cover the whole technical fields from the lower to higher layers, i.e., signal processing, RF/Mixed signal device, antenna, MODEM and network technologies. We have developed dependability improvement method for QZSS Short Message. We have also developed RF-IC and modules like sample-hold circuit for high speed and low power wireless communication system.

(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, towards the creation of novel current-injection graphene THz laser-transistors, we developed an ultrafast graphene laser-transistor device process technology demonstrating world-first single-mode lasing at 5.2 THz by using our original distributed feedback dual-gate device structure. Another important achievement is on high-speed, high-power, high-electron-mobility transistors (HEMTs) based on InGaAs- and GaN-based quantum-well heterostructures. Improved breakdown-voltage performances were verified in InP- and GaN-based HEMTs by introducing a unique slant field plate structure integrated with the gate electrode.

(3) Ultrahigh-Speed Optical Communication

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

This year, we successfully demonstrated a single-channel 5.12 Tbit/s transmission over 300 km using non-coherent Nyquist pulses, and 3.84 Tbit/s, 64 QAM transmission using coherent Nyquist pulses with a spectral efficiency as high as 10.6 bit/s/Hz. Furthermore, we proposed a new high-speed optical communication system with

extremely high security by combining a Quadrature Amplitude Modulation/Quantum Noise Stream Cipher (QAM/QNSC) technology and a Quantum Key Distribution (QKD) technology. The fastest bit rate of 70 Gbit/s was transmitted over 100 km in quantum cryptography.

(4) Applied Quantum Optics

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

The study on ultra-high-speed semiconductor laser with external cavity is being continued. It was confirmed that the frequency response characteristic of a laser diode can be controlled by introducing a hybrid modulation scheme which modulates cavity loss and injection current simultaneously. It becomes clear that the scheme can also control the frequency chirp and contribute to enhance the dispersion tolerance in optical fiber transmission. For the study of narrow linewidth semiconductor laser, it was confirmed that stable operation can be realized by reducing mechanical noise in the optical negative feedback system we proposed. Furthermore, it was confirmed that optical Nyquist pulse was able to be generated by harmonic superposition of RF signals to the LN Mach Zehnder modulator.

(5) Information Storage Systems

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

By developing novel high areal-density perpendicular recording with bit-patterned media and thermal assist recording technique, we have achieved areal density of 5 Tbit/inch^2, which is five times of the current density. Storage system technology to enhance the data transfer rate was also developed. Signal processing for multi-track recording is investigated for fast data transfer and high areal densities. Two-dimensional magnetic recording is developed to read two tracks simultaneously with a reader to increase the data transfer rate.

(6) Quantum-Optical Information Technology

Our goal is to develop quantum information devices utilizing quantum interaction between photons and electrons in solids.

In 2016, we have achieved (1) unpolarized single-photon generation with true randomness from diamond, (2) observation of local-field effects on optical coherent transients of semiconductor quantum dots, and (3) controlled introduction of single gold nanoparticles to a nanofiber surface and the first measurement of the polarization response of this device.

Research Laboratory of Ultrahigh-Speed Optical Communication

Advanced optical communication technologies approaching the Shannon limit

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

[Research Target and Activities]

With the vast growth of Internet traffic, it has become increasingly important to realize a high-capacity and high-speed network. This laboratory aims to achieve a global ultrahigh-speed optical network by engaging in the research of ultrashort pulse and coherent transmission. This year, we successfully demonstrated a single-channel 5.12 Tbit/s-300 km transmission using non-coherent Nyquist pulses, and a 3.84 Tbit/s, 64 QAM coherent Nyquist pulse transmission with a spectral efficiency of 10.6 bit/s/Hz. In addition, we proposed a new high-speed optical communication system with extremely high security by combining a Quadrature Amplitude Modulation/Quantum Noise Stream Cipher (QAM/QNSC) technology where a coherent multi-level signal is hidden in quantum noise and a Quantum Key Distribution (QKD) technology where secure key is delivered with an extremely weak laser light. The fastest bit rate of 70 Gbit/s was successfully transmitted over 100 km in quantum cryptography (Fig. 1).

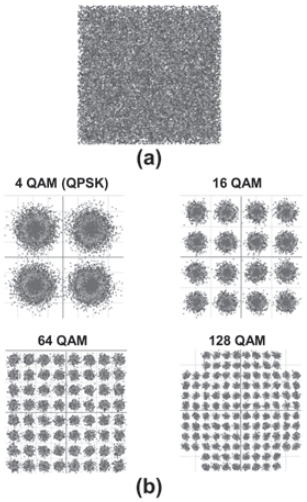


Fig. 1. 4~128 QAM signal after 100 km transmission (a) before decryption, (b) after decryption.

[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.

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

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

[Papers]

[1] M. Nakazawa, M. Yoshida, T. Hirooka, K. Kasai, and T Hirano, "Real-time 70 Gbit/s, 128 QAM quantum noise stream cipher transmission over 100 km with secret keys delivered by continuous variable quantum key distribution system," ECOC 2016, W.4.P1.SC5.59, September (2016).

[2] M. Yoshida, K. Yoshida, K. Kasai, and M. Nakazawa, "1.55 μm hydrogen cyanide optical frequency-stabilized and 10 GHz repetition-rate-stabilized mode-locked fiber laser," Opt. Express, vol. 24, no. 21, pp. 24287-24296, October (2016).

[3] D. Suzuki, K. Harako, T. Hirooka, and M. Nakazawa, "Single-channel 5.12 Tbit/s (1.28 Tbaud) DQPSK transmission over 300 km using non-coherent Nyquist pulses," Opt. Express, vol. 24, no. 26, pp. 29682-29690, December (2016).

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Applied Quantum Optics

Research on Innovative Highly Functional Photonic Semiconductor Devices

Highly Functional Photonics Hiroshi Yasaka, Professor

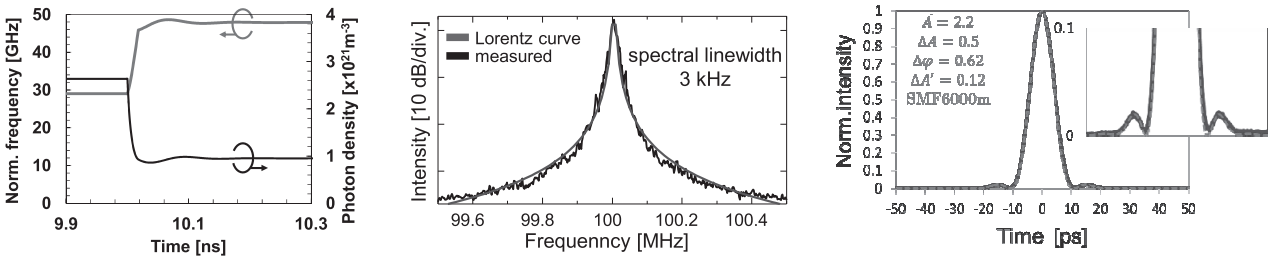
[Research Target and Activities]

Novel functional photonic devices including high function laser diode (LD) sources are being investigated to explore new-generation photonic network systems.

The study on ultra-high-speed semiconductor laser with external cavity is being continued. It was confirmed that the frequency response characteristic of a LD can be controlled by introducing a hybrid modulation scheme where cavity loss and injection current of the laser are modulated simultaneously. It is confirmed that the modulation scheme can also control the frequency chirp of the output optical signal and enhance its dispersion tolerance for transmission in optical fiber.

The study on compact and narrow linewidth semiconductor laser sources is also being proceeded by applying the optical negative feedback method. It was confirmed that the spectral linewidth can be reduced stably by removing vibration noise using a cage system.

Furthermore, the study on a flat-top optical frequency comb generation is being carried out by using a Mach-Zehnder modulator (MZM). It was confirmed that optical Nyquist pulse was able to be generated by a simple scheme with harmonic superposition of RF signals to the modulator.



Results for hybrid modulation laser (left), compact narrow linewidth semiconductor laser (center), and optical Nyquist pulse generation using an MZM (right).

[Staff]

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

[Profile]

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

[Papers]

[1] S. Mieda, N. Yokota, W. Kobayashi, and H. Yasaka, "Ultra-Wide-Bandwidth Optically-Controlled DFB Laser with External Cavity," IEEE Journal of Quantum Electronics, vol. 52, No. 6, p. 2200107, 2016. / DOI 10.1109/JQE.2016.2557489

[2] N. Yokota and H. Yasaka, "Operation Strategy of InP Mach-Zehnder Modulators for Flat Optical Frequency Comb Generation," IEEE Journal of Quantum Electronics, vol. 52, No. 8, p. 5200207, 2016. - DOI 10.1109/JQE.2016.2583921

[3] S. Mieda, N. Yokota, R. Isshiki, W. Kobayashi, and H. Yasaka, "Frequency response control of semiconductor laser by using hybrid modulation scheme," Optics Express, vol. 24, No. 22, pp. 25824-25831, 2016. - DOI 10.1364/OE.24.025824

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Advanced Wireless Information Technology

For realization of the next generation mobile network

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

[Research Target and Activities]

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

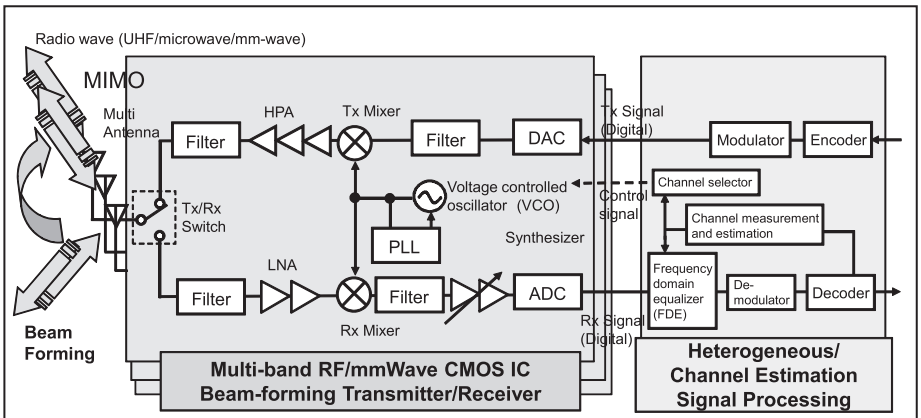

Fig. The target system of
Advanced Wireless Information Technology Laboratory.

We have developed dependability improvement method for QZSS Short Message. We have also developed RF-IC and modules like sample-hold circuit for high speed and low power wireless communication system.

[Staff]

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

[Profile]

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

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

[Papers]

[1] K. Norishima, *et al.*, "Demodulation Characteristics of a 20GHz-band Direct RF Undersampling Receiver," in Proc. 2016 Asia-Pacific Microwave Conference (APMC 2016), TU4C-1, 6 Dec. 2016.
[2] K. Ohya, *et al.*, "Efficient random access control scheme with reservation channel for QZSS short message SS-CDMA communication," IEEE Wireless Communications and Networking Conference 2016 (WCNC2016), pp. 2611-2616, April 2016.
[3] K. Ohya, *et al.*, "Experimental evaluation of timing synchronization accuracy for QZSS short message synchronized SS-CDMA communication," 27th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communication (PIMRC2016), pp. 493-498, Sept. 2016.

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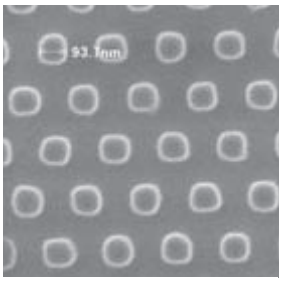
Information Storage System

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, which is estimated to reach to 40 Zetta-byte in 2020. High areal density magnetic recording is the key technology to store the extremely large capacity information. 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 Terabit/inch^2 and ultimately exceeding 5 Terabit/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.



Fabricated sample of bit patterned media.

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 shown in the figure is a promising candidate. We have revealed the possibility of an areal density of 5 Terabit/inch^2 in conjunction with heat assisted recording. We revealed that the thermal stability of the bit-patterned media is observed as the write error rate, not only the amplitude reduction of the written bits. We proposed that high gradient of heat assisted recording is a good way to achieve high areal densities.

Research on information storage systems is being carried out. Novel signal processing for high data transfer rate by parallel reading of multi-track on a disk was developed. was investigated. It was theoretically demonstrated that the data transfer rate of properly designed system was successfully improved according to the number of tracks.

[Staff]

Professor: Hiroaki Muraoka, PhD (since 2000)
Associate Professor: Simon J. Greaves, PhD (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 developed micromagnetic simulation for magnetic recording to investigate the potential of future storage devices. He received his Ph.D in 1993 from Salford University, UK.

[Papers]

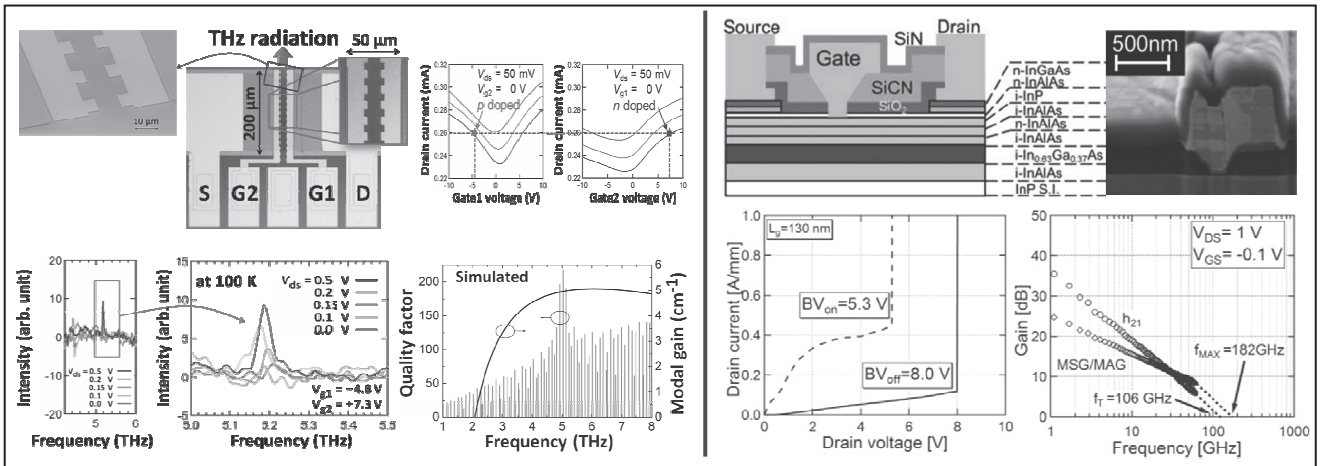
[1] T. Nakamura, S. Matsumoto, M. Tezuka, S. Izumi, and H. Muraoka, “Comparison of Distance Limiting Methods for Risk-aware Data Replication in Urban and Sburban Area,” J. Inf. Proc., 24, 2, 381-389, March 2016.
[2] S. J. Greaves, Y. Kanai, H. Muraoka, “Microwave-Asssited Magnetic Recording on Dual-Thickness and Dual-Layer Bit Patterned Media,” IEEE Trans. Magn., 52, 7, 3000904, July 2016.

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]



Left: SEM and microscope images of the fabricated DFB-DG-GFET and its ambipolar characteristics (top), measured emission spectra at 100K demonstrating single-mode lasing and simulated Q factor and gain spectra (bottom), right: cross sectional view and TEM image of the fabricated InP-based HEMT incorporating a slant field plate (top), measured drain current-voltage property demonstrating an improved breakdown voltages and current-gain cutoff and maximum oscillation frequencies (bottom).

We are developing novel, integrated electron devices and circuit systems operating in the terahertz (THz) region. This fiscal year, toward creation of graphene-based terahertz lasers, we have fabricated our original distributed feedback dual-gate graphene FETs (DFB-DG-GFETs), and succeeded in world-first single-mode lasing operation at 5.2 THz at 100K. Another important achievement is on microwave and millimeter-wave high-electron-mobility transistors (HEMTs) based on compound semiconductor materials such as indium-gallium arsenide (InGaAs) and gallium-nitride (GaN). Improved breakdown voltage performances in these HEMTs were achieved by introducing a unique slant field plate integrated with a gate electrode.

[Staff]

Professor: Taiichi OTSUJI, Dr. Eng.
Associate Professor: Tetsuya SUEMITSU, Dr. Eng.
Assistant Professor: Akira SATOU, Dr. Comp. Sci.
Research Fellow: Victor RYZHII, Ph.D.
Research Fellow: Takayuki WATANABE, Dr. Eng. Secretary: Kayo UENO

[Profile]

Taiichi OTSUJI: received the Dr. Eng. deg. from Tokyo Tech., Japan, in 1994. After working for NTT Labs., Japan, since 1984, he joined Kyutech in 1999, as an Assoc. Prof., being a prof. from 2002. Since 2005, he has been a Prof. at RIEC, Tohoku Univ., Japan. Recipient of the Outstanding Paper Award of the 1997 IEEE GaAs IC Symposium. Distinguished Lecturer, Electron Device Society, IEEE, since 2013. Member of IEEE (Fellow), OSA (Senior), MRS, SPIE, IEICE, and JSAP.
Tetsuya SUEMITSU: received Dr. Eng. from Waseda Univ., Japan, in 2000. Research Scientist, NTT Labs., Japan (1994- 2006); Visiting Scientist, MIT, USA (2002-2003); Assoc. Prof., Tohoku Univ., Japan (2006-). Recipient of the Best Paper Award, IEICE (2003), and the ELEX Best Paper Award, IEICE (2007). Member of IEEE(Senior), APS, JSAP, and PSJ.

[Papers]

[1] D. Yadav, S. Boubanga-Tombet, T. Watanabe, S. Arnold, V. Ryzhii, and T. Otsuji, "Terahertz wave generation and detection in double-graphene layered van der Waals heterostructures," 2D Mater., vol. 3, pp. 045009-1-8, 2016.
[2] Y. Koseki, V. Ryzhii, T. Otsuji, V. V. Popov, and A. Satou, "Giant plasmon instability in dual-grating-gate graphene field-effect transistor," Phys. Rev. B, vol. 93, pp. 245408-1-5, Jun. 2016.
[3] T. Hosotani, T. Otsuji, and T. Suemitsu, "Achievement of balanced high frequency and high breakdown by InGaAs-based high-electron-mobility transistors with slant field plates," Appl Phys. Exp., vol. 9, pp. 114101-1-3, Oct. 2016.

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Quantum-Optical Information Technology

Development of optoelectronic devices for quantum information and communication technology

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

[Research Target and Activities]

Our goal is to develop quantum information devices utilizing quantum interaction between photons and electrons in solids. In 2016, we have achieved (1) unpolarized single-photon generation with true randomness from diamond, (2) observation of local-field effects on optical coherent transients of semiconductor quantum dots, and (3) controlled introduction of single gold nanoparticles to a nanofiber surface and the first measurement of the polarization response of this device.

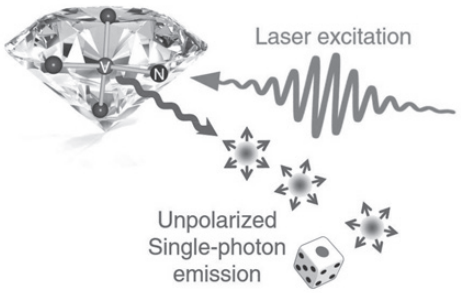

Fig. Schematic picture of unpolarized single-photon generation using a compound defect, a nitrogen vacancy center (NV center), in a diamond.

[Staff]

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

[Profile]

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

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

Mark Sadgrove received B.S., M.S., and Ph.D degrees in science from University of Auckland. He was a Postdoctoral Fellow in The University of Electrocommunications, a Postdoctoral Fellow in Gakushuin University, and an Assistant Professor (nontenured) in The Center for Photonic Innovations, The University of Electrocommunications

[Papers]

[1] Y. Mitsumori, S. Matsuura, S. Uchiyama, K. Edamatsu, and M. Nakayama, "Cavity effect on a biexciton in a CuCl microcavity," Phys. Rev. B **94**, 115308 (2016)
[2] M. Sadgrove, S. Wimberger, and S.N. Chormaic. "Quantum coherent tractor beam effect for atoms trapped near a nanowaveguide," Sci. Rep. **6**, 28905 (2016)
[3] N. Abe, Y. Mitsumori, M. Sadgrove, and K. Edamatsu, "Dynamically unpolarized single-photon source in diamond with intrinsic randomness," Sci. Rep. **7**, 46722 (2017)

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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, three 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, (4) Information Content, (5) Real-world computing, (6) Nano-Molecular Devices, (7) Nano-Bio Hybrid Molecular Devices.

The goals and achievements in the fiscal year 2015 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) To develop a high sensitive microvibration measuring system, we worked on the fabrication of high sensitive strain sensors on a Si wafer and the design of detection circuits with low noise. On the work of high frequency magnetic field measuring system, we have succeeded in imaging the distribution of high frequency magnetic field generated from electronic parts by our proposed system. In addition, motion capture system using magnetic markers was studied to improve its position accuracy. The study about nanostructured magnetic materials using magnetic nanoparticles was carried out for the creation of novel functional materials.

(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) We are devoting in deepening of the understanding human spatiotemporal perceptual processes of audio-vestibular information. Moreover, We also study how the sense of presence and verisimilitude are affected by physical factors involved in multimodal

content consisting of auditory, visual and vestibular information. These studies are particularly important to realize future multi-modal sensory information processing and communication systems. Moreover, we continued to develop advanced acoustic systems. These include 3D virtual auditory displays based on our accumulated knowledge of human auditory space perception, sensing and reproduction system based on High-order Ambinonics consisting of over 100 channels, and 252-ch real-time binaural spatial sound sensing technique (SENZI), which can comprehensively record 3D sound space information. Moreover, we are formulating the unified design theory of binaural systems using spherical microphone array and spatially dense HRTF (head-related transfer function) datasets. These topics 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 spread of spatial attention and found that there are multiple stages of the attention mechanisms: one for facilitating the area around the attention focus and one for selecting information at the focused location. Secondly, we investigated cultural influences on color categorization by a categorical color naming experiment. The results revealed that Japanese has 19 fundamental color categories (including 11 basic color categories) and that ‘mizu’ is one of a fundamental color category while it was not in a similar study executed 30 years ago, suggesting evolution of a fundamental color category.

(4) Information Content

(Aims) We aim to conduct comprehensive research on a variety of technologies rerated to interactive content which creates new value through interactions with humans.

(Achievements)

This year we proposed a new 6DOF marker design of our magnetic 3D tracking system for dexterous 3D interactions. We also proposed and evaluated a novel IMU-based 3D user interface in mobile augmented reality scenario using head-mounted display. Moreover, we proposed a shape-shifting wall display which can dynamically change its position, arrangement and shape according to varying contexts.

(5) Real-world computing

(Aims) This laboratory aims at understanding the mechanism underlying adaptive and resilient behavior of animals from the viewpoint of decentralized control schemes.

(Achievements)

The main contributions achieved in 2016 are summarized as follows: (1) we have proposed a novel decentralized control method on the basis of a concept called TEGOTAE, a Japanese concept describing how well a perceived reaction matches an expectation. We implemented this control mechanism into a snake-like robot, and confirmed that this robot can negotiate narrow aisle by exhibiting a locomotion pattern called concertina; (2) we have succeeded the gait transition from walk to trot to gallop with a real physical quadruped robot. This result has been advertised in the press; (3) we have formulated a novel decentralized control mechanism for hexapod locomotion on the basis of TEGOTAE concept. We have demonstrated its validity with a real physical hexapod robot.

(6) Nano-Molecular Devices

(Aims) This laboratory aims at developing molecular-scaled electronic devices that allow advanced information processes based on various nano-structured materials and nanotechnology.

(Achievements) Firstly, we integrated Infrared absorption spectroscopy (IRAS) in a multiple internal reflection (MIR) geometry with silicon-based micro-fluidic channels to allow detection and separation of DNA molecules in the micro-channels. Secondly, we have fabricated front-side illuminated dye-sensitized solar cells (DSSCs) with a thin film of vertically oriented TiO_2 nanotubes used as the negative electrode. We examined the effects of $TiCl_4$ treatment on the performance on the basis of the derived cell parameters. We also proposed a novel fabrication method to dramatically increase the crystal size of organometal perovskite by more than 20 times as compared with previously reported values. Because of reduced grain boundaries and increased crystal order in perovskite layers, the lateral charge transport was significantly improved.

(7) Nano-Bio Hybrid Molecular Devices.

(Aims) Our research activities focus on development of sophisticated molecular-scale devices through the combination of well-established microfabrication techniques and various soft materials, such as biomaterials and organic materials.

(Achievements) We proposed an efficient method for constructing artificial cell membrane sensors for drug screening systems. The key channel-integration step was accelerated and the probability of sensor construction was improved from ~6% to 67%. We also reconstructed circuits of cultured neurons by using micropatterned glass substrates and succeeded in guiding the direction of neuronal signal transmission to the intended orientation. Another achievement is fabrication of a hydrogen gas sensor using piezoelectric poly(vinylidene fluoride) film sandwiched between thin films of palladium. Simple simulation model was also proposed to explain the basic characteristics of the sensor responses.

Electromagnetic Bioinformation Engineering

Communication with human body

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

[Research Target and Activities]

To develop a high sensitive microvibration measuring system, we worked on the fabrication of high sensitive strain sensors on a Si wafer and the design of detection circuits with low noise. On the work of high frequency magnetic field measuring system, we have succeeded in imaging the distribution of high frequency magnetic field generated from electronic parts by our proposed system. In addition, motion capture system using magnetic markers was studied to improve its position accuracy. The study about nanostructured magnetic materials using magnetic nanoparticles was carried out for the creation of novel functional materials.

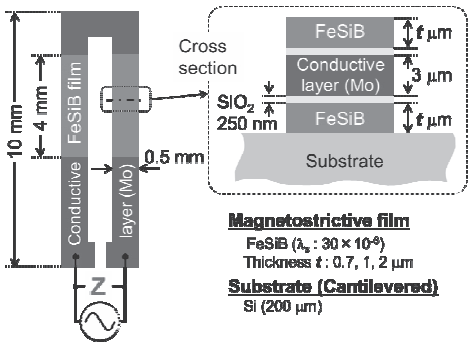

Fig. 1 Schematic diagram of high sensitive strain sensor

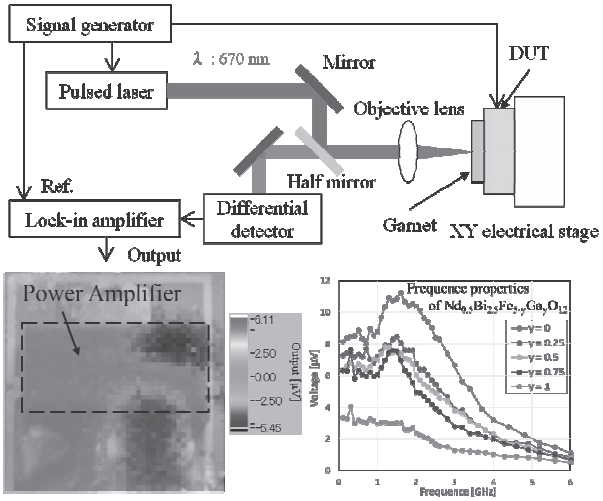

Fig. 2 High frequency magnetic field measuring system using magneto-optical crystal probe

[Staff]

Professor: Kazushi Ishiyama, Dr.
Associate Professor: Shuichiro Hashi, Dr.
Assistant Professor: Yoshiaki Hayashi, Dr.
Research Assistant: Kaoru Arai

[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] Hiroaki Kikuchi, Shingo Kamata, Chihiro Sumida, Tomoo Nakai, Shuichiro Hashi, Kazushi Ishiyama, "Enhancement of impedance change at low frequency in a thin-film magnetoimpedance element," Journal of Magnetism and Magnetic Materials, Vol. 420, pp. 269-274, December (2016).
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Advanced Acoustic Information Systems

Development of next generation communication systems

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

[Research Target and Activities]

The main interest of this laboratory is the study of information processing by the human auditory system. At the same time, we aim to realize a 'comfortable' sound environment by exploiting digital signal processing techniques. One typical example is the development of new type of three-dimensional auditory displays, which present sound images by simulating the transfer functions for the sound paths from the sound sources to the listeners' external ears. Another example is the proposal of 3D sound field information sensing systems. These systems are expected to convey a high-quality virtual sound space, which is keenly sought for multimedia communications, cyberspace systems and virtual reality systems. Moreover, in FY2016, we put a lot of effort to develop systems to acquire 3D sound-space information capable of saving, transmitting, and reproducing it accurately at a distant place. In regards to three-dimensional sound space information recording using microphone arrays, we realized a real-time system using a spherical microphone array and FPGAs. From a psychoacoustical point of view, we also investigated the effect of self-motion, including head rotation, on the auditory space perception.

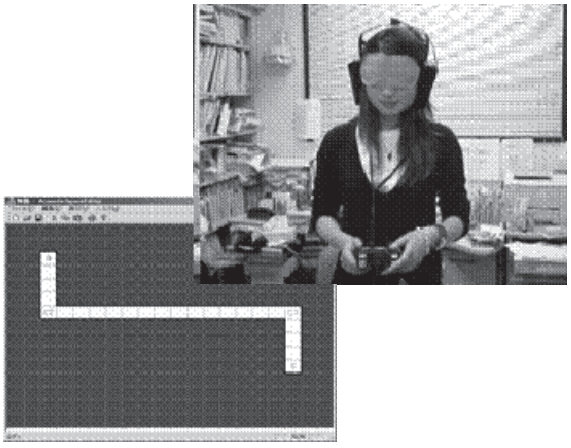

Fig. 1 Application for the training of spatial cognition using a high-definition virtual auditory display

[Staff]

Professor: Yôiti Suzuki, Dr., Associate Professor: Shuichi Sakamoto, Dr.,
Assistant Professor: Zheng Lie Cui, Dr., Jorge Treviño, Dr.,
Research Staff: Cesar Daniel Salvador, Dr.,
Technical Staff: Fumitaka Saito

[Profile]

Yôiti Suzuki graduated from Tohoku University in 1976 and received his Ph. D. degree in ’81 also from Tohoku University. His research interests include psychoacoustics and digital signal processing of acoustic signals. He served as president of the Acoustical Society of Japan from 2005 to ’07 and is a board member of the Japan VR Society since ‘14. 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 2004, also from Tohoku University. His research interests include human auditory and multisensory information processing and development of advanced multimodal information systems. He is serving as a board member of the Acoustical Society of Japan since 2016

[Papers]

[1] Honda, A., Ohba, K., Iwaya, Y., & Suzuki, Y., "Detection of Sound Image Movement during Horizontal Head Rotation," i-Perception, 7(5) (2016).
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[3] S. Hu, J. Trevino, C. Salvador, S. Sakamoto, J. Li, Y. Suzuki, "A local representation of the head-related transfer function," J. Acoust. Soc. Am., 140(3), EL285-EL290 (2016).

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Visual Cognition and Systems Laboratory

Understanding human visual system for the better communication with visual information

Visual Cognition and Systems Satoshi SHIOIRI, Professor
Cognitive Brain Functions Ichiro KURIKI, Associate Professor
Attention and Learning Systems Chia-hue TSENG, 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 proposed a model of spatial attention that has two stages with different functions. Some studies reported broad spatial spreads around attended locations, while others reported a selection of information at the attention focus. We showed that these discrepancies could be attributed to the different stages of the attention process. The attention model proposed could predict different attention effects for different visual processes. Secondly, we investigated the universal or cultural dependence of the mechanisms of color information processing. 57 naïve participants named each of 330 color chips with a single word, and the result was analyzed by k-means clustering technique. 19 color categories, including universal 11 basic color terms, were derived and 3 of them were unique in Japanese. A color name 'mizu (light blue)' was not included as a basic color in a similar study conducted 30 years ago, but 98% of participants in the present study used 'mizu.' Our study revealed the evolution of basic color names in the past 30 years by an objective and quantitative measure.

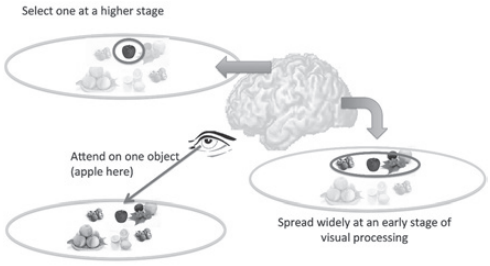

Figure. Attention spreads at an early stage of visual processing but selects local information at a later stage.

[Staff]

Professor : Satoshi Shioiri, Ph.D.
Associate Professor : Ichiro Kuriki, Ph.D.
Associate Professor : Chia-huei Tseng, 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.
Chia-huei TSENG Dr. is an expert on visual attention, perception, and learning. She received her B.S. and B.M.S. from National Taiwan University and PhD from The University of California, Irvine, U.S.A.. She was a post-doc researcher at Laboratory of Vision Research at the Center for Cognitive Science, Rutgers University, New Jersey. She has designed science outreach activities to engage community participation in many Asian cities. She was the founder and director of Baby Scientist Program and Infant Research Lab in Hong Kong. Before joining Tohoku University as associate professor in 2016, she was a university professor in Taiwan and Hong Kong.

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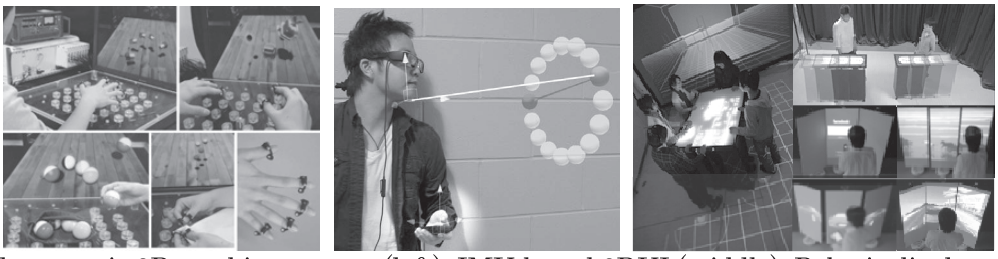
Information Content

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 proposed a new 6DOF marker design of our magnetic 3D tracking system for dexterous 3D interactions. We also proposed and evaluated a novel IMU-based 3D user interface in mobile augmented reality scenario using head-mounted display. Moreover, we proposed a shape-shifting wall display which can dynamically change its position, arrangement and shape according to varying contexts.



A novel magnetic 3D tracking system (left), IMU-based 3DUI (middle), Robotic displays (right)

[Staff]

Professor: Yoshifumi Kitamura, Dr.
Assistant Professor: Kazuki Takashima, 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] Kasim Ozacar, Juan David Hincapié-Ramos, Kazuki Takashima, and Yoshifumi Kitamura, 3D Selection Techniques for Mobile Augmented Reality Head-Mounted Displays, Interacting with Computers,Vol.29, No.4, 579-591, December 2016.

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[3] Kazuki Takashima, Takafumi Oyama, Yusuke Asari, Ehud Sharlin, Saul Greenberg, and Yoshifumi Kitamura, Study and Design of a Shape-Shifting Wall Display, In Proceedings of Conference on Designing of Interactive Systems, pp. 796-806, June 2016. 【Honorable Mention Award】

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Nano-Bio Hybrid Molecular Devices

Development of novel bio-devices through the combination of nanotechnology and biomaterials

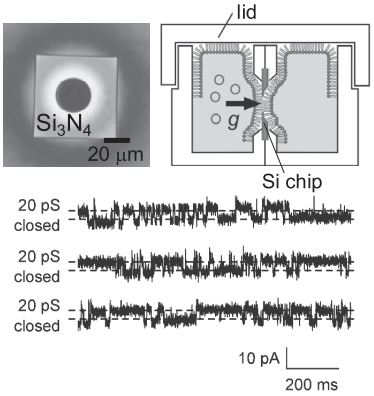
Nano-Bio Hybrid Molecular Devices: Ayumi Hirano-Iwata, Professor

[Research Target and Activities]

Our research activities focus on development of sophisticated molecular-scale devices through the combination of well-established microfabrication techniques and various soft materials, such as biomaterials and organic materials.

1. Formation of artificial cell membrane sensors

We proposed an efficient method for constructing artificial cell membranes. Ion-channel integration was accelerated by utilizing a centrifugal force for concentrating channels near the membranes. This method dramatically improves the experimental throughput, leading to the realization of a high-throughput drug screening for various membrane proteins. [Biophys. J., **110** (10), 2207-2215 (2016).]



Microfabricated silicon chip for artificial cell membranes.

2. Reconstruction of artificial neuronal networks

We reconstructed circuits of cultured neurons by using micropatterned glass substrates. The signal between the neurons was transmitted unidirectionally in the intended orientation. This work provides a practical guideline for designing functional neuronal networks *in vitro* with controlled signal direction. [Appl. Phys. Lett., **109** (4), 043703 (2016).]

3. A Hydrogen gas sensor with an organic piezoelectric film

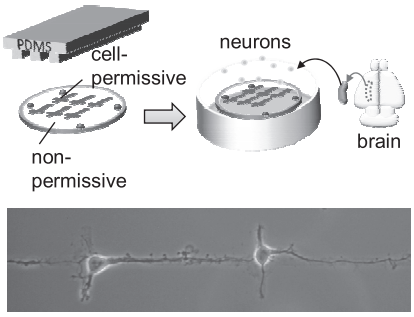
We fabricated a hydrogen gas sensor based on a piezoelectric poly(vinylidene fluoride) film sandwiched between thin films of palladium. Simple simulation model was also proposed to explain the basic characteristics of the sensor responses. [Appl. Phys. Lett., **109** (4), 043703 (2016).]

[Staff]

Professor: Ayumi Hirano-Iwata, Dr.

[Profile]

Ayumi Hirano-Iwata 2016 – RIEC, Tohoku University, Japan, Professor, Doctorate of Science. Memberships: The Japan Society of Applied Physics, The Surface Science Society of Japan.



Micropatterning of neurons.

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[1] A. Hirano-Iwata, Y. Ishinari, M. Yoshida, S. Araki, D. Tadaki, R. Miyata, K. Ishibashi, H. Yamamoto, Y. Kimura, M. Niwano, "Reconstitution of Human Ion Channels into Solvent-free Lipid Bilayers Enhanced by Centrifugal Forces," Biophys. J., **110** (10), 2207-2215 (2016).

[2] H. Yamamoto, R. Matsumura, H. Takaoki, S. Katsurabayashi, A. Hirano-Iwata, M. Niwano, "Unidirectional signal propagation in primary neurons micropatterned at a single-cell resolution," Appl. Phys. Lett., **109** (4), 043703 (2016).

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Nano-Molecular Devices

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

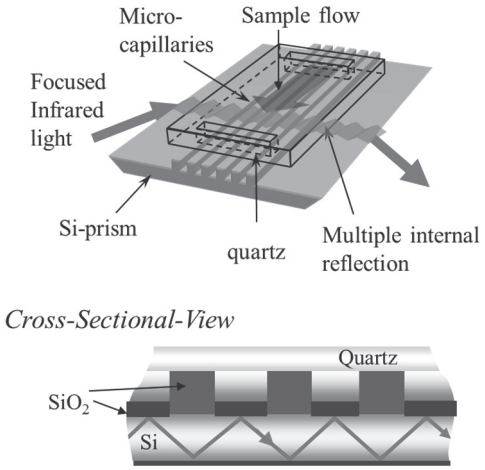
Nano-Molecular Devices: Michio Niwano, Professor

[Research Target and Activities]

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

(1) Infrared absorption spectroscopy (IRAS) in a multiple internal reflection (MIR) geometry is integrated with silicon-based micro-fluidic channels to allow detection and separation of DNA molecules in the micro-channels. The applicability of this approach was demonstrated with a representative test case: transport of single-stranded DNA molecules in the micro-fluidic channels.

(2) We have fabricated front-side illuminated dye-sensitized solar cells (DSSCs) with a thin film of vertically oriented TiO2 nanotubes used as the negative electrode. Titanium tetrachloride (TiCl4) treatment was applied on the TiO2 nanotube film to improve the performance of the DSSCs. We examined the effects of TiCl4 treatment on the performance on the basis of the derived cell parameters.



DNA detection system using micro-channel electrophoresis conjugated with MIR-IRAS.

(3) Organometal perovskite materials have been widely used in various kinds of devices. In those devices, grain boundaries and structural disorder in the perovskite layer interfere the charge transport and increase recombination probability. We proposed a novel fabrication method to increase the crystal size by more than 20 times as compared with previously reported values. Because of reduced grain boundaries and increased crystal order in perovskite layers, the lateral charge transport was significantly improved.

[Staff]

Professor: Niwano, Michio Dr.

[Profile]

Michio Niwano 1998 – 2017 RIEC, Tohoku University, Japan, Professor, Doctorate of Science. Memberships: The Electrochemical Society (ECS), The Japan Society of Applied Physics (JSAP), The Surface Science Society of Japan (SSSJ).

[Papers]

[1] R. Kojima, Y. Kimura, Teng Ma, K. Ishibashi, D. Tadaki, R. A. Rosenberg, A. Hirano-Iwata, and M. Niwano, "Fabrication and characterization of front-illuminated dye-sensitized solar cells with anodic titanium oxide nanotubes." J. Electrochem. Soc., **164**, H78-H84 (2017).

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[3] T. Miyoshi, K. Ishibashi, K. Miyamoto, A. Hirano-Iwata, Y. Kimura, M. Niwano, "Label-free detection of DNA molecules moving in micro -fluidic channels by infrared absorption spectroscopy." Sens. Actuators B-Chem., **238**, 917-922 (2017).

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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.

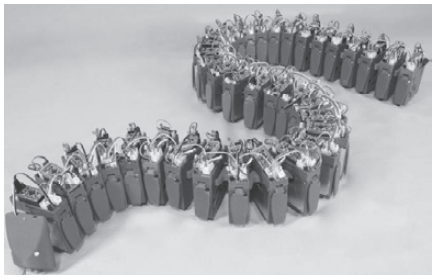

Fig.1: Snake-like robot that exhibits scaffold-based locomotion

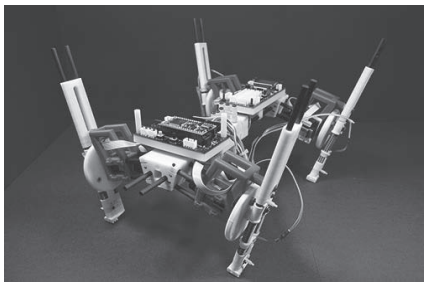

Fig.2: Quadruped robot that exhibit various gait patterns

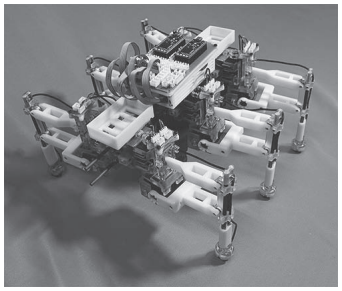

Fig.3: Hexapod robot that exhibits adaptive interlimb coordination.

[Staff]

Professor: Akio ISHIGURO, Dr.
Associate Professor: Takeshi KANO, Dr.
Assistant Professor: Dai OWAKI, 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, 2012 IEEE/RSJ JCTF Novel Technology Paper Award for Amusement Culture Finalist, Living Machines 2012 Best Paper Award.

[Papers]

[1] T. Kano, R. Yoshizawa, and A. Ishiguro, "TEGOTAE-based Control Scheme for Snake-like Robots That Enables Scaffold-based Locomotion", Living Machines 2016, pp. 441-448, 2016.
[2] D. Owaki and A. Ishiguro, "A Quadruped Robot Exhibiting Spontaneous Gait Transitions from Walking to Trotting to Galloping," Scientific Reports, 7:277, doi: 10.1038/s41598-017-00348-9, 2017
[3] M. Goda, S. Miyazawa, S. Itayama, D. Owaki, T. Kano, and A. Ishiguro, "Understanding Interlimb Coordination Mechanism of Hexapod Locomotion via "TEGOTAE"-based Control", Living Machines 2016, pp. 441-448, 2016.

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Research Targets and Activities of Systems & Software Division

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

— Software Construction: Reliable and high-level software.
— Computing Information Theory: Fundamental theory of new software.
— Communication Network: Symbiotic computing.
— Environmentally Conscious Secure Information System: Embedded system security
— Soft Computing Integrated System: Brainmorphic hardware.
— New Paradigm VLSI System: Post-binary CMOS-based VLSI computing.
— Structure of Information Society (Visitor Section).

An overview of research results from Apr. 2016 to Mar. 2017 of these fields except the visitor section is described in this section.

(1) Software Construction

We research on theoretical foundations for flexible and reliable programming languages, and develop SML#, a new programming language in the ML family embodying our research results. The major results of the 2015 academic year include the following. (1) We have developed a type theory and compilation method for Natural Join operation in a polymorphic language. (2) We have completed the development of a concurrent GC system, including its correctness proof and performance evaluation, and have integrated it in the SML# compiler. The results were presented at ACM ICFP 2016. (3) We have developed the JSON manipulation primitives and have integrated them in the SML# compiler. The results were presented at ECOOP 2016.

(2) Computing Information Theory

Rewriting systems are mathematical formalisms which can offer both flexible computing and effective reasoning with equations. Our research focuses on theoretical features of rewriting systems and applications to automated theorem proving, algebraic specifications, and functional and logic programming languages. The main results of this year are as follows. (i) We have proposed a new theoretical framework of nominal rewriting systems and implemented a confluence prover based on this framework. (ii) We have developed an automated ground confluence prover AGCP for term rewriting systems, based on rewriting induction with non-orientable equations.

(3) Communication Network Systems

We have done the following studies on Cooperative Distributed Knowledge Information Processing and its applications. (a) Application of Active Information Resources: Using a

prototype of the AIR-based personal knowledge base system implemented in this year, support functions of both the activation and the recall of AIR-based memory was validated. (b) Intelligent Network-oriented Services: The service personalization method based on mobile agents had been evaluated and a multiagent-based network data analysis system is designed and a part of the system implemented. The effectiveness of the proposed mechanism was demonstrated by experiments. (c) Agent-based Internet of Things (AIoT) framework: The agentification method of equipment such as IoT devices and robots, and the organizing method of cooperative AIoT agents group were designed and evaluated through the prototyping and experiment.

(4) Environmentally Conscious Secure Information System

We are studying future secure information communication systems from theories to implementation technologies for constructing advanced information and communication infrastructures in a safe and secure manner. In this year, we has succeeded in developing the world's most efficient Advanced Encryption Standard (AES) cryptographic processing circuit whose energy consumption is reduced by more than 50% of the current level, and also developed a new formal method for verifying both functionality and security property of tamper-resistant cryptographic hardware. In addition, we have developed and demonstrated a method for improving stability and uniformity of hardware-oriented physically unclonable functions used for individual identification, cryptographic operations and so on.

(5) Soft Computing Integrated System

We are working on a novel high-performance, highly-efficient, flexible, and robust brain-inspired brainmorphic computer hardware system, in particular, through physical complex-networked dynamical process using an analog VLSI as a core component. Results of this year include the followings. (1) We proposed a brain-body whole organism computing paradigm. As the first step to realize a hardware system based on this paradigm, we investigated three neural network models for a "core-self" system. (2) For a dynamics/algorithm sub-conscious/conscious hybrid computer system, we developed a large-scale chaotic neural network integrated circuit. In addition, we built a prototype hybrid computational hardware system using this chaotic neuro-IC as a core element. We also demonstrated the ability and efficiency of the proposed hardware.

(6) New Paradigm VLSI System

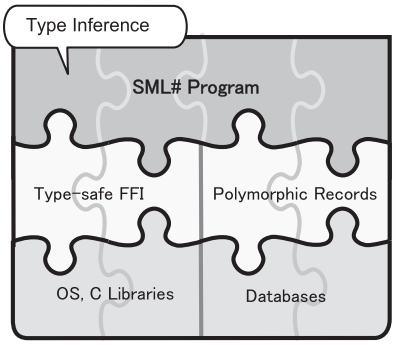
Our research activity is to solve the several limitations such as power dissipation, performance and reliability due to the present binary-CMOS-based VLSI computing. The key approach to breaking through such limitations is primarily the following two ways: the logic-in-memory architecture based on nonvolatile logic, and the brainware LSI (BLSI) computing, which would open up a novel VLSI chip paradigm, called a "new-paradigm VLSI system." This year, we have succeeded to design and implement MTJ (Magnetic Tunnel Junction)-based nonvolatile logic LSI with dynamic write error masking scheme, single-ended nonvolatile LUT (Look Up Table) circuit with on-chip variation compensation, and energy-harvesting nonvolatile processor. The above research results have reported 13 journal papers and 13 peer-reviewed international conference papers.

Software Construction Laboratory

Foundations for Developing High-level and Reliable Programming Languages

Software Construction Atsushi Ohori, Professor
Reliable Software Development Katsuhiro Ueno, Associate 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, 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, direct C interface and seamless integration of SQL.

The major results of the 2015 academic year include the following. (1) We have developed a type theory and compilation method for Natural Join operation in a polymorphic language. (2) We have completed the development of a concurrent GC system, including its correctness proof and performance evaluation, and have integrated it in the SML# compiler. The results were presented at ACM ICFP 2016. (3) We have developed the JSON manipulation primitives and have integrated them in the SML# compiler. The results were presented at ECOOP 2016.

[Staff]

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

[Profile]

Atsushi Ohori. He was born in 1957. He received his BA degree in Philosophy from University of Tokyo, 1981; received his Ph.D. degree in Computer and Information Science from University of Pennsylvania, 1989. He worked for Oki Electric Industry from 1981 until 1993. 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.

Katsuhiro Ueno. He was born in 1981. He received the Doctor of Philosophy (Information Sciences) degree from Tohoku University, 2009. He joined Research Institute of Electrical Communication (RIEC), Tohoku University as an assistant professor in 2009. Since 2016, he has been an associate professor at the same institute.

[Papers]

[1] Katsuhiro Ueno, Atsushi Ohori: A Fully Concurrent Garbage Collector for Functional Programs on Multicore Processors, ACM International Conference on Functional Programming (ICFP 2016), pp. 421-433, September, 2016.
[2] Atsushi Ohori, Katsuhiro Ueno, Tomohiro Sasaki, Daisuke Kikuchi: A Calculus with Partially Dynamic Records for Typeful Manipulation of JSON Objects, European Conference on Object-Oriented Programming (ECOOP 2016), pp. 18:1--18:25, July, 2016.
[3] Katsuhiro Ueno, Atsushi Ohori: A foreign language interface from ML to shell, New Generation Computing, Vol. 34, No. 3, pp. 239--256, August, 2016.

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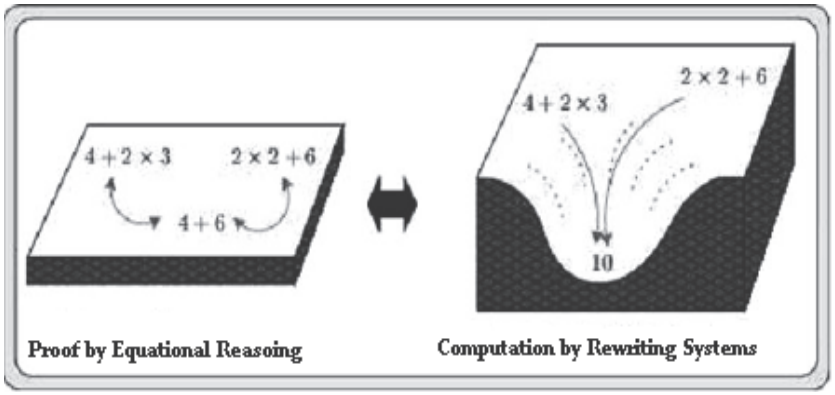
Computing Information Theory

Towards a New Software Paradigm Arising from Computation and Proof

Computing Information Theory Yoshihito TOYAMA, Professor

[Research Target and Activities]

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



[Staff]

Professor : Toyama, Yoshihito Dr
Assistant Professor : Kikuchi, Kentaro Dr

[Profile]

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

[Papers]

[1] Takahito Aoto and Kentaro Kikuchi, Nominal confluence tool, Lecture Notes in Computer Science, Vol.9706, pp.173-182, 2016.
[2] Vincent van Oostrom and Yoshihito Toyama, Normalisation by random descent, Leibniz International Proceedings in Informatics, Vol.52, pp.32:1-32:18, 2016.
[3] Takahito Aoto and Yoshihito Toyama, Ground confluence prover based on rewriting induction, Leibniz International Proceedings in Informatics, Vol.52, pp.33:1-33:12, 2016.

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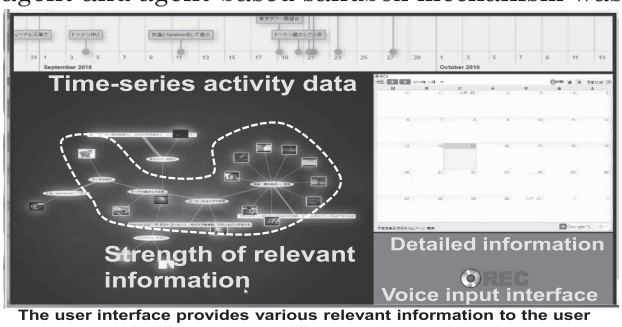
Communication Network Systems

Support for Cooperation and Communication between Human and Systems

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

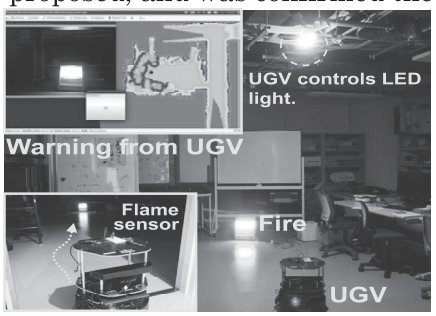
[Research Target and Activities]

In this year, the following studies had been done. (a) Active Information Resources: An AIR-based acquisition function of memory fragments was developed to support human memory recall. (b) System's Fundamental Technologies for Agent-based IoT: An adaptive control and plan construction functions had been developed and its effectiveness was also demonstrated by experiments. (c) Personalization Method of Secure Service: A personalization method of secure services using mobile agent and agent-based sandbox mechanism was proposed, and was confirmed the availability.

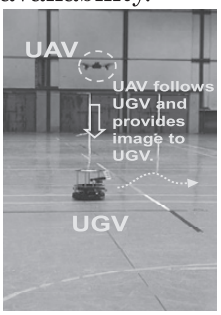


The user interface provides various relevant information to the user to support episodic memory recall.

AIR-based memory recall support system



(a) UGV checks the room for fire hazards.



(b) UAV cooperates with UGV.

Agent-based IoT devices' cooperation

[Staff]

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

[Profile]

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

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

[Papers]

[1] T. Uchiya, M. Hibino, I. Takumi, T. Kinoshita, "Design and Implementation of Agent Environment for Developing Nash-Q Learning Agents," International Journal of Energy, Information and Communications, Vol.8, No.1, pp.39-50, Feb. 2017.
[2] K. Sasai, Y. Tanimura, H. Takahashi, G. Kitagata, T. Kinoshita, "An Agent-based Data Analytics Support Tool for Network Management Intelligence," International Journal of Energy, Information and Communications, Vol.8, No.1, pp.51-64, Feb. 2017.
[3] K. Sasai, Y.-P. Gunji, T. Kinoshita, "Extremely localized interaction in a market model," Artificial Life and Robotics, Vol.22, No.1, pp.125-129, Mar. 2017.

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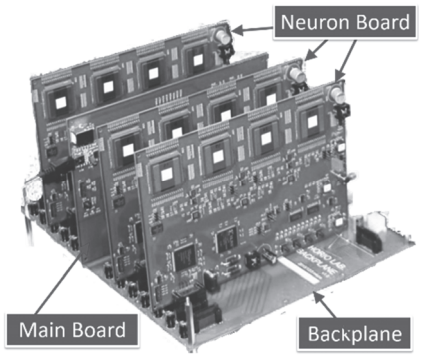
Soft Computing Integrated System

Brainmorphic Computing Hardware System

Soft Computing Integrated System Yoshihiko Horio, Professor

[Research Target and Activities]

We are working on a novel high-performance, highly-efficient, flexible, and robust brain-inspired brainmorphic computer hardware system. In particular, we focus on an information processing through physical complex-networked dynamical process, and its implementation as a computational hardware system using an analog VLSI as a core component. Toward the final goal, we are developing integrated circuit and device technologies suitable for the brainmorphic computer systems, such as VLSI technologies for high-dimensional chaotic networks and large-scale complex systems, VLSI circuits and architectures for ultra-low-power asynchronous neural network systems, and compact and low-power devices/circuits for adaptive synaptic connections. At the same time, we are developing a massively-parallel brainmorphic computational architecture, which is very much different from that of the conventional digital computers. We further intend to realize an autonomous brain-inspired computer with a sense of self and consciousness based on a complex network with dynamic change in spatiotemporal network state and structure.



A dynamics/algorithm sub-conscious/conscious hybrid computer system.

[Staff]

Professor : Yoshihiko Horio, Ph.D.

[Profile]

Yoshihiko Horio received the B.E., M.E., and Ph.D. degrees in electrical engineering from Keio University, Japan, in 1982, 1984, and 1987, respectively. He is currently a Professor with the Research Institute of Electrical Communication, Tohoku University, Japan. From 1987 to 2016, he was with Department of Electronic Engineering, Tokyo Denki University, Japan, being a Professor from 2000. From April 1992 to March 1994, he was a Visiting Professor at Center for Telecommunications Research, Columbia University, U.S.A. His current research interests are in the area of neuromorphic and brainmorphic hardware systems based on complex physical dynamics, mixed analog/digital VLSI circuit design, and high-order brain-inspired VLSI systems with consciousness, self, and embodiment. Dr. Horio received the 3rd Hiroshi Ando Memorial Young Engineer Award (1990), the IEEE Myril B. Reed Best Paper Award (1991), NCSP Best Paper Awards (2005, 2007, 2008, 2013), IEEE NDES Best Paper Awards (2005, 2007), ISCS-ISIS Best Paper Award (2008), and IEICE NOLTA Lifetime Achievement Award (2016).

[Papers]

[1] William A. Borders, et al., "Analogue spin–orbit torque device for artificial-neural-network-based associative memory operation," Applied Physics Express, vol. 10, pp. 013007-1 - 013007-4, Dec. 2016.

[2] Takemori Orima, and Yoshihiko Horio, "An improved parameter value optimization technique for the reflectionless transmission-line model of the cochlea," in Proceedings of the 2017 International Conference on Artificial Life and Robotics, pp. 136-139, Jan. 20, 2017.

[3] Takayoshi Fujino, and Yoshihiko Horio, "A switched-current golden ratio encoder circuit," in Proceedings of International Symposium on Nonlinear Theory and Its Applications, pp. 526-529, Nov. 2016.

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Environmentally Conscious Secure Information System

Advanced information security technology

Environmentally Conscious Secure Information System, Naofumi Homma, Professor

[Research Target and Activities]

We are studying future secure information communication systems from theories to implementation technologies for constructing advanced information and communication infrastructures in a safe and secure manner. In this year, we has succeeded in developing the world's most efficient Advanced Encryption Standard (AES) cryptographic processing circuit whose energy consumption is reduced by more than 50% of the current level (Fig. 1), and also developed a new formal method for verifying both functionality and security property of tamper-resistant cryptographic hardware. In addition, we have developed and demonstrated a method for improving stability and uniformity of hardware-oriented physically unclonable functions used for individual identification, cryptographic operations and so on.

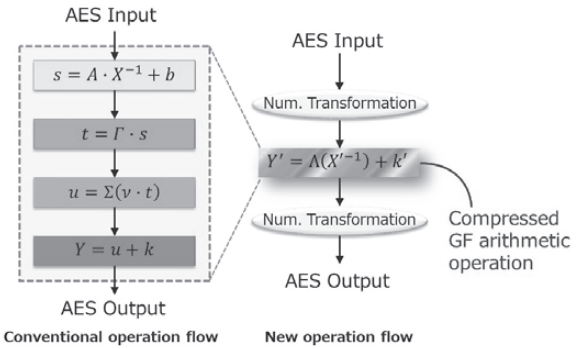

Fig. 1: New operation compression technology for AES cryptographic processing.

[Staff]

Professor: Naofumi Homma, Ph. D

[Profile]

Naofumi Homma received the PhD degrees in information sciences from Tohoku University, Sendai, Japan, in 2001. From 2001 to 2009, he was an Assistant Professor in the Graduate School of Information Sciences at Tohoku University. From 2009 to 2016, he was an Associate Professor in the Graduate School of Information Sciences at Tohoku University. Since 2016, he has been a Professor in the Research Institute of Electrical Communication, Tohoku University. In 2009-2010 and 2016-2017, he was a visiting professor at Telecom ParisTech, Paris, France. His research interests include computer arithmetic, EDA methodology, and hardware security. He received the IP Award at the LSI IP Design Award in 2005, the Best Paper Award at the Workshop on Synthesis and System Integration of Mixed Information Technologies in 2007, the RIEC Award in 2012, the Best Symposium Paper Award at IEEE International Symposium on Electromagnetic Compatibility (EMC 2013) in 2013, and the Best Paper Award at the IACR Conference on Cryptographic Hardware and Embedded Systems (CHES 2014) in 2014.

[Papers]

[1] Rei Ueno, Naofumi Homma, Yukihiro Sugawara, and Takafumi Aoki "Formal Approach for Verifying Galois Field Arithmetic Circuits of Higher Degrees," IEEE Trans. on Computers, , Vol. 66, No. 3, pp. 431-442, March 2017

[2] Yu-ichi Hayashi, Naofumi Homma, Yohei Toriumi, Kazuhiro Takaya, and Takafumi Aoki, "Remote Visualization of Screen Images Using a Pseudo-Antenna that Blends into the Mobile Environment," IEEE Trans. EMC, Vol. 59, No. 1, pp. 24-33, February 2017

[3] Rei Ueno, Sumio Morioka, Naofumi Homma, and Takafumi Aoki, "A High Throughput/Gate AES Hardware Architecture by Compressing Encryption and Decryption Datapaths," CHES 2016, LNCS 9813, pp. 538-558, Springer-Verlag, August 2016

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New Paradigm VLSI System Research Group

Realization of a New-Paradigm VLSI-Computing World

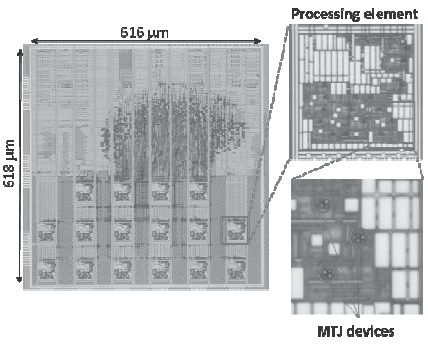


Fig. 1. MTJ-based nonvolatile logic LSI with dynamic write error masking scheme

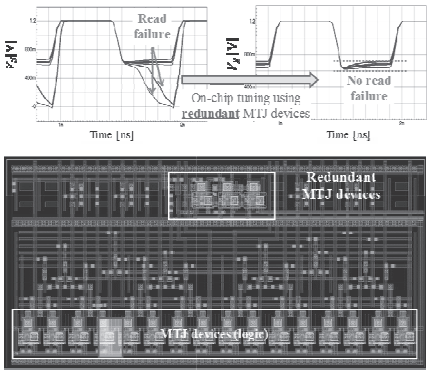


Fig. 2. Single-ended nonvolatile LUT circuit using redundant MTJ devices with on-chip variation compensation

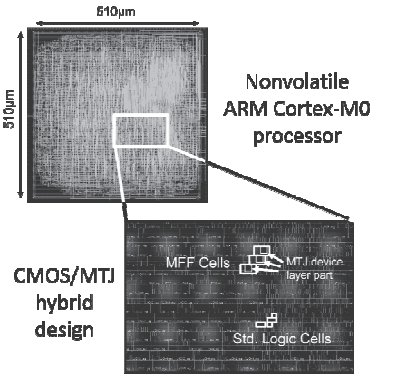


Fig. 3. Energy-harvesting nonvolatile ARM Cortex-M0 processor using CMOS/MTJ devices

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

[Research Target and Activities]

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

This year, we have succeeded to design and implement MTJ (Magnetic Tunnel Junction)-based nonvolatile logic LSI with dynamic write error masking scheme (Fig. 1), single-ended nonvolatile LUT (Look Up Table) circuit with on-chip variation compensation (Fig. 2), and energy-harvesting nonvolatile processor (Fig. 3).

[Staff]

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

[Profile]

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

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

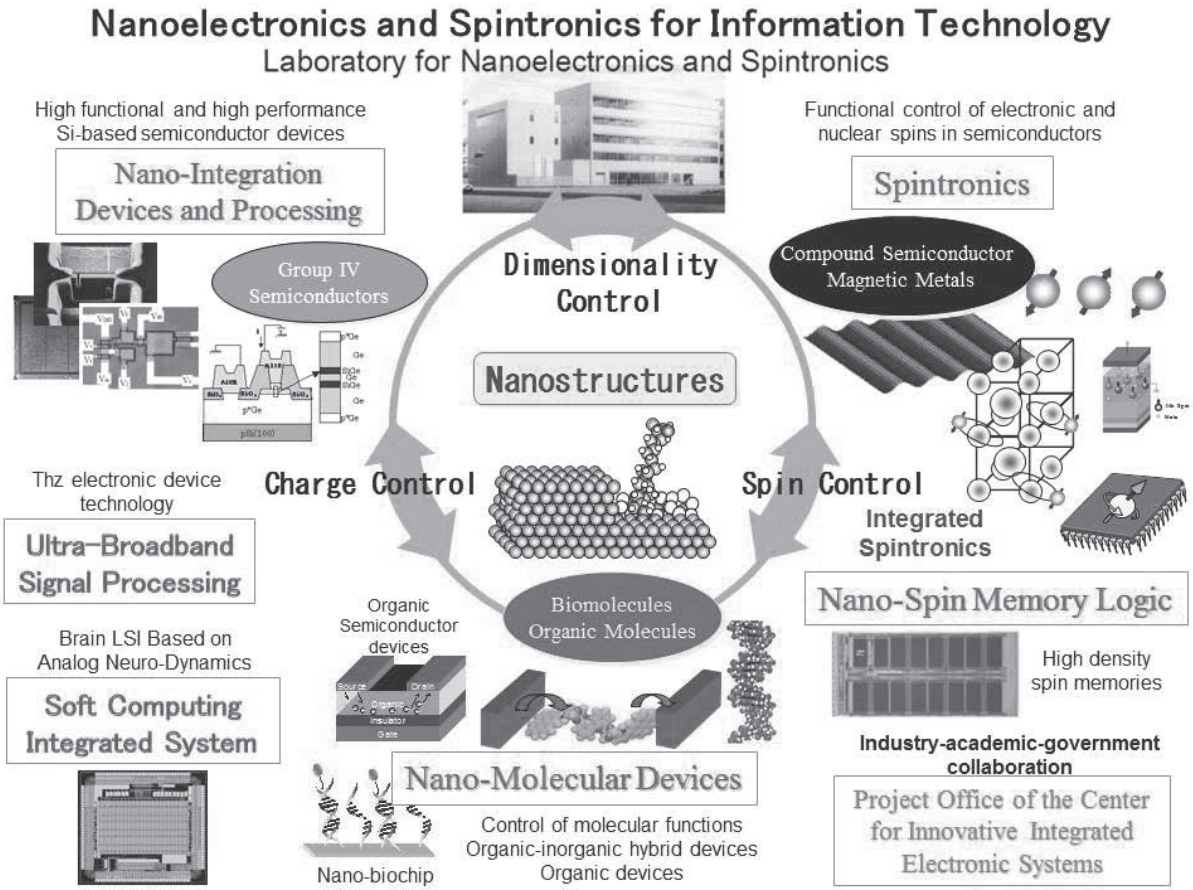
[Papers]

[1] T. Hanyu, et al., "Standby-Power-Free Integrated Circuits Using MTJ-Based VLSI Computing," ***Proc. IEEE***, vol.104, no.10, pp.1844-1863, Oct. 2016.
[2] D. Suzuki, et al., "Design of a Variation-Resilient Single-Ended Nonvolatile 6-Input Lookup Table Circuit with a Redundant-MTJ-Based Active Load for Smart IoT Applications," ***IET Electronics Letters***, vol. 53, No. 7, pp. 456-458, Mar. 2017.
[3] N. Onizawa, et al., "Sudden Power-Outage Resilient In-Processor Checkpointing for Energy-Harvesting Nonvolatile Processors," ***IEEE Transactions on Emerging Topics in Computing***, 2017 (to appear).

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 project office of the Center for Innovative Integrated Electronic Systems, and the groups of Ultra-Broadband Signal Processing and Soft Computing Integrated System. 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 2016

Nano Integration

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

(1) Toward the development of computation algorithms utilizing quantum parallelism, we have proposed a quantum associative memory system. We discussed a Hamiltonian to simulate key input for the associative memory and confirmed that the memory capacity of the system increases greatly in comparison with a conventional associative memory.

(2) Epitaxial growth of heavily C or B doped Si on Si(100) has been demonstrated by low-energy ECR plasma CVD without substrate heating. Moreover, it has been found that an epitaxial $Si_{0.5}Ge_{0.5}$ alloy film grown without substrate heating shows n-type properties with as high carrier mobility as 660 $cm^2 V^{-1} s^{-1}$.

(3) A local motion detection LSI inspired by motion stereo vision in human vision system has been developed. A virtual connection scheme, in which connection information is calculated by a dedicated circuit, makes it possible to reduce chip area by 12 times compared with another scheme utilizing a look-up table implementing into an on-chip memory.

(4) The availability of a novel spin-orbit troupe device, which works as a non-volatile analog memory for synaptic weights, has been demonstrated in an associative memory operation in a Hopfield network. An effect of learning, Hebb and anti-Hebb learning to compensate associative error due to device mismatch, is successfully confirmed for several 3x3 binary patterns.

(5) The correlation between the structure of neuronal circuitry and its temporal-spatial dynamics has been investigated by using numerical simulation focusing on the relation between the modular structure of neuronal circuitry and the frequency of synchronized network bursts. Is has been quantitatively clarified that network bursts frequency increases with increasing of the degree of connection.

● Soft Computing Integrated System (Y. Horio)

(1) We proposed a brain-body whole organism computing paradigm. As the first step to realize a hardware system based on this paradigm, we investigated three neural network models required for a “core-self” system.

(2) For a dynamics/algorithm sub-conscious/conscious hybrid computer system, we developed a large-scale chaotic neural network integrated circuit. In addition, we built a prototype hybrid computational hardware system using this chaotic neuro-IC as a core element. We also demonstrated the ability and efficiency of the proposed hardware.

(3) We proposed a design method for the reflection-less transmission-line model of Cochlea by applying optimization techniques whose objective function and constraints are explicitly derived as mathematical formulae.

(4) We proposed a switched-current golden ratio analog-to-digital converter circuit, which is robust against fluctuation in device characteristics, environmental parameters and so on, based on complex mathematical modeling technique, and fabricated it as an integrated

circuit.

Spintronics and Information Technology

● **Spintronics (H. Ohno and S. Fukami)**

Our research activities focus on realizing low-power functional spintronic devices. The outcomes in the last fiscal year are as follows: (1) investigation of the electronic structure of (Ga,Mn)As by angle-resolved photoemission spectroscopy, which shows (Ga,Mn)As is in the vicinity of metal-insulator transition and its Fermi level lies in the valence band with spin-orbit interaction, (2) evaluation of electric-field modulation ratio of exchange stiffness constant of CoFeB from magnetic domain structures, (3) evaluation of device size dependence of damping constant in CoFeB free layer from ferromagnetic resonance (FMR) in nanoscale magnetic tunnel junction with perpendicular (in-plane) magnetization in free (reference) layer, (4) investigation of the mechanism of FMR linewidth enhancement of NiFe on topological insulator $(BiSb)_2Te_3$, (5) clarification of the effect of motional narrowing on the magnetization dynamics in thin films with interfacial anisotropy, (6) clarification of underlying mechanism for analog-like behavior in PtMn/[Co/Ni]-based spin-orbit torque switching device from investigation of the device size dependence of magnetization reversal mode.

In addition, the following outcomes have been obtained through cooperative researches under national projects.

1. Research activities in "Research and Development of Spintronics Material and Device Science and Technology for a Disaster-Resistant Safe and Secure Society" Program under Research and Development Project for ICT Key Technology to Realize Future Societies by MEXT: (1) achievement of the world-smallest magnetization switching energy of 6.3 fJ for a highly resistive magnetic tunnel junction by electric-field-induced switching, (2) demonstration of associative memory operation by artificial neural network with analog spintronics devices, (3) understanding of effect of electric-field-induced anisotropy modulation on current-induced magnetization switching from current-pulse width dependence of switching probability in nanoscale magnetic tunnel junction under in-plane magnetic field.
2. Research activities in "Achieving Ultimate Green IT Devices with Long Usage Times without Charging" Program under Impulsing Paradigm Change through Disruptive Technologies Program of CSTI: (1) realization of sub-ns, field-free, low-current spin-orbit torque induced magnetization switching by improving configuration and material of a newly-developed device, (2) investigation of magnetization switching modes in elliptic magnetic tunnel junctions from the probability of switching induced by magnetic field or current pulses, (3) clarification of critical role of W deposition condition on spin-orbit torque induced magnetization switching of nanoscale W/CoFeB/MgO.

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

The goal of our research is to explore the terahertz frequency range by creating novel

integrated electron devices and circuit systems. III-V- and graphene-based active plasmonic heterostructures for creating new types of terahertz lasers and ultrafast transistors are major concerns. By making full use of these world-leading device/circuit technologies, we are developing future ultra-broadband wireless communication systems as well as spectroscopic/imaging systems for safety and security. The followings are the major achievements in 2016FSY.

1. Creation of graphene-based current-injection terahertz lasers

   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. Towards the creation of novel current-injection graphene THz laser-transistors, we developed an ultrafast graphene laser-transistor device process technology demonstrating world-first single-mode lasing at 5.2 THz at 100K by using our original distributed feedback dual-gate device structure. (presented at CLEO 2017, and 74th DRC.)

2. Development of ultrafast & high-power transistor devices and process technology

   We developed high-speed, high-power, high-electron-mobility transistors (HEMTs) based on InGaAs- and GaN-based quantum-well heterostructures. Improved breakdown-voltage performances were verified in InP- and GaN-based HEMTs by introducing a unique slant field plate structure integrated with the gate electrode. (published in Appl. Phys. Exp. 9, 114101 (2016).)

Nano-Molecular Devices

● Nano-Molecular Devices (M. Niwano)

1. Label-free detection of DNA molecules moving in micro-fluidic channels by infrared absorption spectroscopy: Infrared absorption spectroscopy (IRAS) in a multiple internal reflection (MIR) geometry is integrated with silicon-based micro-fluidic channels to allow detection and separation of DNA molecules in the micro-channels. The applicability of this approach was demonstrated with a representative test case: transport of single-stranded DNA molecules (oligonucleotides) in the micro-fluidic channels.
2. Fabrication and characterization of front-illuminated dye-sensitized solar cells with anodic titanium oxide nanotubes: We have fabricated front-side illuminated dye-sensitized solar cells (DSSCs) with a thin film of vertically oriented TiO2 nanotubes used as the negative electrode. Titanium tetrachloride (TiCl4) treatment was applied on the TiO2 nanotube film to improve the performance of the DSSCs. We examined the effects of TiCl4 treatment on the performance on the basis of the derived cell parameters.
3. Fabrication and characterization of high-quality perovskite films with large crystal grains: Organometal perovskite materials have been widely used in various kinds of devices. In those devices, grain boundaries and structural disorder in the perovskite layer interfere

the charge transport and increase recombination probability. We proposed a novel fabrication method to dramatically increase the crystal size by more than 20 times as compared with previously reported values. Because of reduced grain boundaries and increased crystal order in perovskite layers, the lateral charge transport was significantly improved.

● **Nano-Bio Hybrid Molecular Devices（A. Hirano-Iwata）**

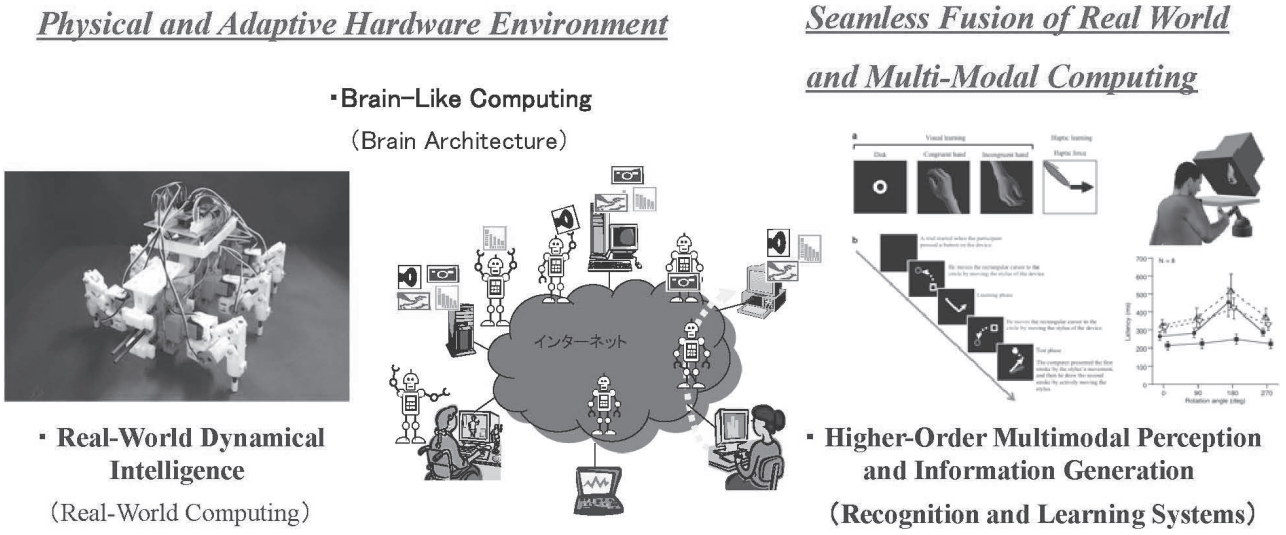
Our research activities focus on development of sophisticated molecular-scale devices through the combination of well-established microfabrication techniques and various soft materials, such as biomaterials and organic materials. We proposed an efficient method for constructing artificial cell membrane sensors for drug screening systems. The key channel-integration step was accelerated and the probability of sensor construction was improved from ~6% to 67%. We also reconstructed circuits of cultured neurons by using micropatterned glass substrates and succeeded in guiding the direction of neuronal signal transmission to the intended orientation. Another achievement is fabrication of a hydrogen gas sensor using piezoelectric poly(vinylidene fluoride) film sandwiched between thin films of palladium. Simple simulation model was also proposed to explain the basic characteristics of the sensor responses.

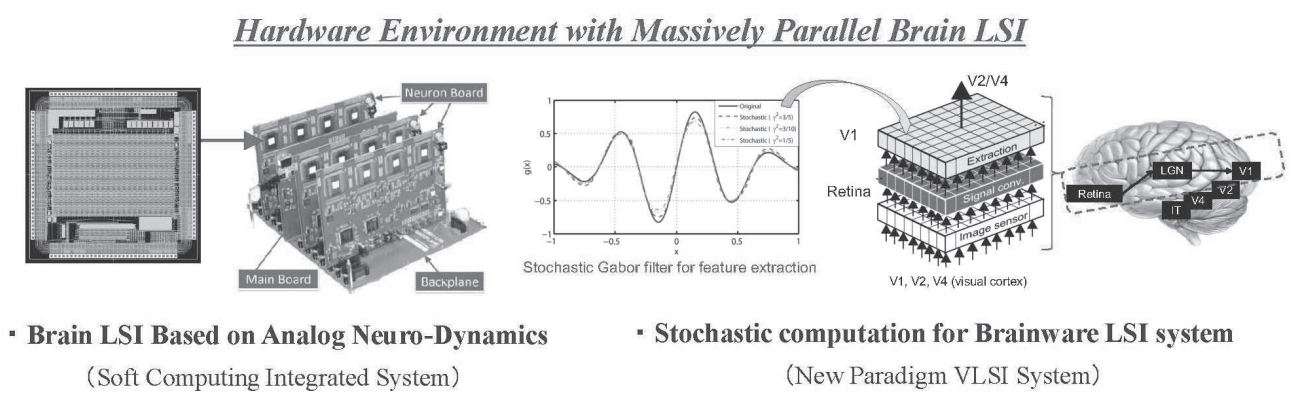
Research Targets and Activities of Laboratory for Brainware Systems

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

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

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





[Research Target]

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

New Paradigm VLSI System Section: Rapid progress in recent deep submicron regime has led the capability to realize giga-scaled embedded systems on a chip (SoC), while performance

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

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

Soft Computing Integrated System Section: We are working on a novel high-performance, highly-efficient, flexible, and robust brain-inspired brainmorphic computer hardware system, in particular, through physical complex-networked dynamical process using an analog VLSI as a core component. Toward the final goal, we are developing integrated circuit and device technologies suitable for the brainmorphic computer systems. We further intend to realize an autonomous brain-inspired computer with a sense of self and consciousness based on dynamic and complex changes in spatiotemporal network state and structure.

[Research Activities]

Real-World Computing Section: The main contributions achieved in 2016 are summarized as follows: (1) we have proposed a novel decentralized control method on the basis of a concept called TEGOTAE, a Japanese concept describing how well a perceived reaction matches an expectation. We implemented this control mechanism into a snake-like robot, and confirmed that this robot can negotiate narrow aisle by exhibiting a locomotion pattern called concertina; (2) we have succeeded the gait transition from walk to trot to gallop with a real physical quadruped robot. This result has been advertised in the press; (3) we have formulated a novel decentralized control mechanism for hexapod locomotion on the basis of TEGOTAE concept. We have demonstrated its validity with a real physical hexapod robot.

New Paradigm VLSI System Section: The major contributions achieved in 2016 are summarized as follows: (1) switching variation (and/or probability) of magnetic tunnel junction (MTJ) devices is a serious problem in realizing a nonvolatile logic LSI. We have successfully designed and implemented MTJ-based nonvolatile logic LSI with dynamic write error masking scheme, (2) There is a trade-off between compactness and high reliability in realizing nonvolatile logic LSIs. We have proposed a single-ended nonvolatile LUT (Look Up Table) circuit with a dynamic amplifier, which results in saving the energy consumption of 66 % in comparison with that of a conventional approach, and (3) an energy-harvesting technique is useful to realize Internet-of-Things (IoT) applications, but its power supply is not stable. We have successfully designed an IoT-oriented VLSI processor with MTJ-based nonvolatile devices, which achieves an automated recovery function if the power supply is shut down and then recovered again.

Recognition and Learning Systems Section: We investigated the influence of luminance contrast on the blanking and landmark effects. In the blanking effect, temporarily blanking the target after a saccade improves displacement judgments. In the landmark effect, illusory target displacement occurs when a continuously presented landmark is displaced during a saccade and the target is temporarily blanked after the saccade without displacement. Since these effects involve a transient change in luminance after a saccade, this postsaccadic blanking may activate luminance transient-sensitive systems. We found that both effects depend on a common process for target displacement detection, and that the landmark effect can be regarded as a bias in the decision criterion. These results suggest that changes in luminance, or transient signals, play a critical role in visual stability across saccades.

Soft Computing Integrated System Section: Results of this year include the followings. (1) We proposed a brain-body whole organism computing paradigm. As the first step to realize a hardware system based on this paradigm, we investigated three neural network models for a "core-self" system. (2) For a dynamics/algorithm sub-conscious/conscious hybrid computer system, we developed a large-scale chaotic neural network integrated circuit. In addition, we built a prototype hybrid computational hardware system using this chaotic neuro-IC as a core element. We also demonstrated the ability and efficiency of the proposed hardware. (3) We proposed a

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design method for the reflection-less transmission-line model of Cochlea by applying optimization techniques. (4) We proposed a switched-current golden ratio analog-to-digital converter circuit based on complex mathematical modeling technique, and fabricated it as an integrated circuit.

Recognition and learning systems laboratory

Understanding the human recognition and learning systems

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

[Research Target and Activities]

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

First, we investigated the influence of luminance contrast on the blanking and landmark effects. In the blanking effect, temporarily blanking the target after a saccade improves displacement judgments. In the landmark effect, illusory target displacement occurs when a continuously presented landmark is displaced during a saccade and the target is temporarily blanked after the saccade without displacement. Since these effects involve a transient change in luminance after a saccade, this postsaccadic blanking may activate luminance transient-sensitive systems. We found that both effects depend on a common process for target displacement detection, and that the landmark effect can be regarded as a bias in the decision criterion. These results suggest that changes in luminance, or transient signals, play a critical role in visual stability across saccades. Second, we measured attentional modulation in space near one's own hand by using the flash lag effect. The flash lag effect is a visual illusion resulting from a flash stimulus aligned with a moving stimulus. We found that the magnitude of the flash lag effect was modulated by the hand position. This suggests that the flash lag effect may be a means to investigate the mechanisms underlying attentional prioritization in peri-hand space.

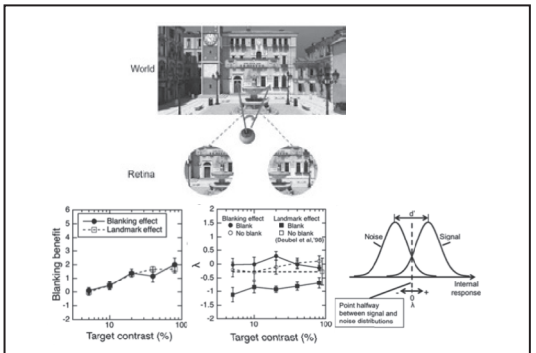

Figure. We found that changes in luminance, or transient signals, play a critical role in visual stability across saccades. The blanking and landmark effects depend on a common process for target displacement detection, and that the landmark effect can be regarded as a bias in the decision criterion.

[Staff]

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

[Profile]

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

[Papers]

1. Matsumiya K, Sato M, Shioiri S: Contrast dependence of saccadic blanking and landmark effects. Vision Research 129, 1-12, 2016.
2. Matsumiya, K., Nishikawa, R., Kuriki, I., Shioiri, S.: "Measurement of attentional modulation in space near hand using flash-lag effect", The 1st International Symposium on Embodied-Brain Systems Science (EmboSS), The University of Tokyo, Tokyo, May 8-9, 2016.

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IT-21 center

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

[Research Target and Activities]

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

1. Development of high-efficient transmission power amplifier module contributing to the low-carbon society

The mobile wireless technology group has been proposing the concept of "Dependable Air," which is a heterogeneous and highly-reliable wireless network. The Dependable Air is able to work even in the event of a big disaster. For realizing the concept of Dependable Air, the mobile group started "Development of high-efficient transmission power amplifier module contributing to the low-carbon society" from 2015 as the Japan Science and Technology Agency (JST) A-STEP type project. In mobile communication systems, power amplifiers (PAs) are one of the most energy consuming device, and PAs are demanded high linearity and high efficiency. In this year, we have fabricated a triple cascode push-pull power amplifier with second harmonic feedback by using 0.18-μm CMOS process. In addition, for realizing heterogeneous wireless network, we have tried field measurement of 3.5-GHz-band small cell indoor-outdoor propagation.

2. Development of High Availability Information Storage Systems

Severe information loss took place due to the damage of storage servers by the East-Japan Great Earthquake. We started research on reliable information storage system 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 available storage system. In 2013, (1) A storage system that realizes 90 % of information can be available even when a half (50%) servers are lost or damaged was developed based on the risk-aware algorism, (2) Simulation of high-speed data-transfer was carried out for parallel-track storage device and software defined network systems, (3) Prototyping and testing of the highly reliable storage system. In 2016, the final practical demonstration was carried out for the anti-disaster storage system implemented into the real local area network of Tohoku University.

[Staff]

Director: Hiroaki Muraoka, Professor

Project Planning Division

Makoto Furunishi, Visiting Professor

Technology Development Division (Mobile Wireless Technology Group)

Noriharu Suematsu, Professor
Suguru Kameda, Associate Professor

Technology Development Division (Storage Technology Group)

Takaki Nakamura, Associate Professor
Hiroshi Matsuoka, Visiting Professor
Masachika Harada, Research Fellow

IT21 Center Mobile Wireless Technology Group

For Realizing Dependable Air

Noriharu Suematsu, Professor (Project Leader)
Suguru Kameda, Associate Professor

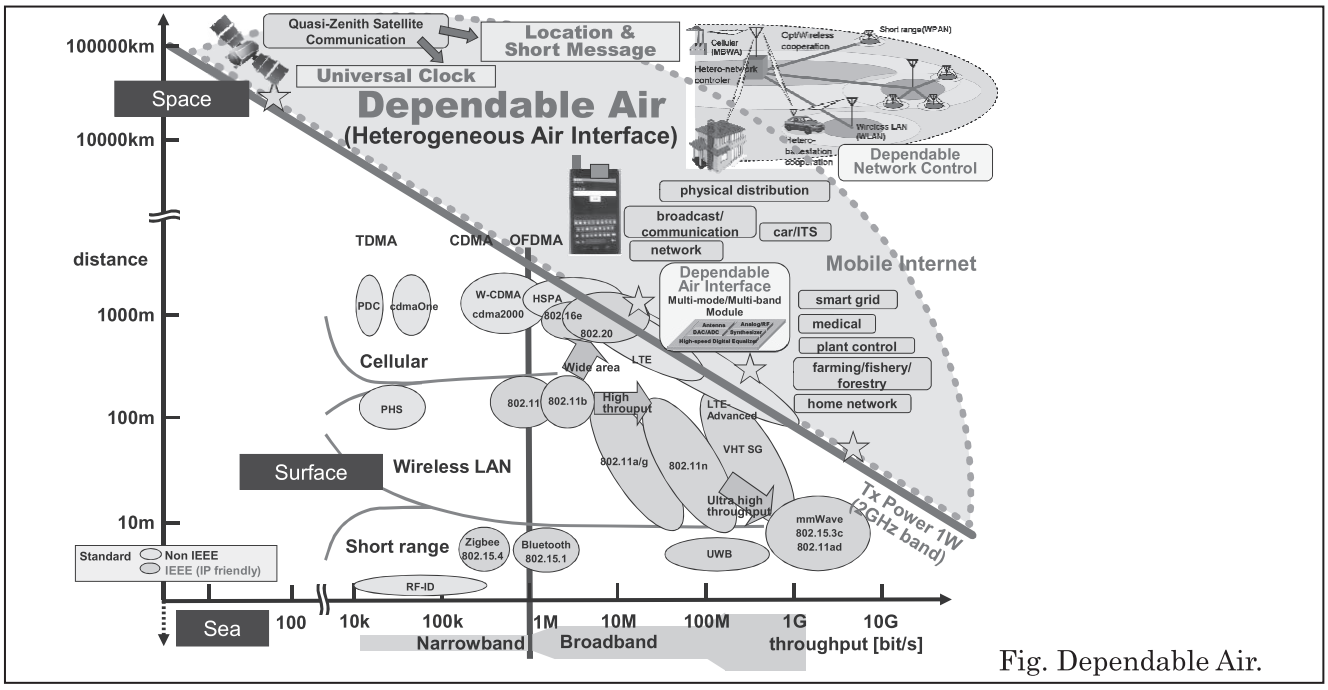

Fig. Dependable Air.

[Research Target and Activities]

Mobile wireless communication technology is one of the significant communication technologies that support the Information and Communication Technology (ICT) society, connected with the high-speed backbone network using optical fiber. Evolution of the mobile wireless communication technology in Japan is indispensable to keep the leadership in this technology area in the world. The mobile wireless technology group has been proposing the concept of "Dependable Air," which is a heterogeneous and highly-reliable wireless network. The Dependable Air is able to work even in the event of a big disaster. For realizing the concept of Dependable Air, the group started the Japan Science and Technology Agency (JST) A-STEP type project "Development of high-efficient transmission power amplifier module contributing to the low-carbon society" from 2015. In addition, for realizing heterogeneous wireless networks such as fifth generation (5G) mobile communication system, we have tried field measurement of 3.5-GHz-band small cell indoor-outdoor propagation.

[Staff]

Professor: Noriharu Suematsu, Ph. D
Associate Professor: Suguru Kameda, Ph. D

[Papers]

[1] H. Fukudome, K. Akimoto, S. Kameda, N. Suematsu, T. Takagi, and K. Tsubouchi, "Measurement of 3.5 GHz Band Small Cell Indoor-Outdoor Propagation: Visualization Method of RSSI in 3-dimensional Geospace (Technology Exhibit)," IEICE Tech. Rep., SR2016-2, Oulu, Finland, May 2016.
[2] H. Fukudome, K. Akimoto, S. Kameda, N. Suematsu, T. Takagi, and K. Tsubouchi, "Measurement of 3.5 GHz Band Small Cell Indoor-Outdoor Propagation in Multiple Environments," European Wireless 2016 (EW2016), Oulu, Finland, May 2016.
[3] H. Fukudome, K. Akimoto, S. Kameda, N. Suematsu, T. Takagi, and K. Tsubouchi, "Modeling Indoor-Outdoor Propagation in Wooden Residential Area at 2.5 GHz and 3.5 GHz Bands," International Conference on Computing, Networking and Communications (ICNC 2017), Silicon Valley, Jan. 2017.

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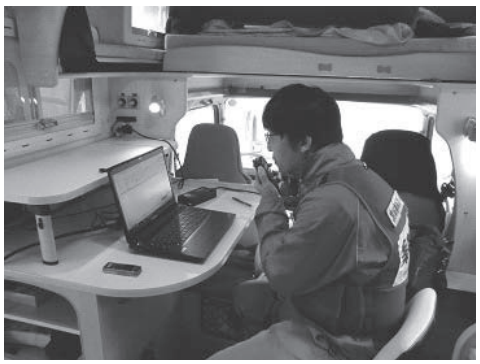
IT21 Center Storage Technology Group

Realization of Highly-available Storage System

Takaki Nakamura, Associate Professor
Hiroshi Matsuoka, Visiting Professor

The 2nd Prototype Highly-Available Storage System for Evaluation of Data Replication Functions



A Snapshot in Field Test of Highly-Available Storage System

[Research Target and Activities]

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

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

[Staff]

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

[Profile]

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

[Papers]

[1] Hitoshi Kamei, Shinya Matsumoto, Takaki Nakamura, and Hiroaki Muraoka, “REC2: Restoration Method Using Combination of Replication and Erasure Coding,” Proc. of 5th IIAI International Congress on Advanced Applied Infomatics (2016), pp 936-941.

[2] Shun Kaneko, Takaki Nakamura, Hitoshi Kamei, and Hiroaki Muraoka, “A Guideline for Data Placement in Heterogeneous Distributed Storage Systems,” Proc. of 5th IIAI International Congress on Advanced Applied Infomatics (2016), pp 942-945.

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Management Office for Safety and Health

Realizing and Maintaining a Safe and Comfortable Environment to Support Research

[Research Target and Activities]

Safety and health seminar

First aid training course

1. Outline of the Management Office for Safety and Health

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

2. Activities by the Management Office for Safety and Health

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

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

[Staff]

Manager: Takahiro Hanyu, Professor

Deputy Manager: Yoichi Uehara, Professor

Nobuyuki Sato, Assistant Professor

Maho Abe, Technical Staff　　Yoshiko Kikuta and Haruka Takahashi, Clerk

Flexible Information System Center

Development and Management of Flexible Information System

[Research Target and Activities]

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

Figure 1 RIEC network system

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

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

[Staff]

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

[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.

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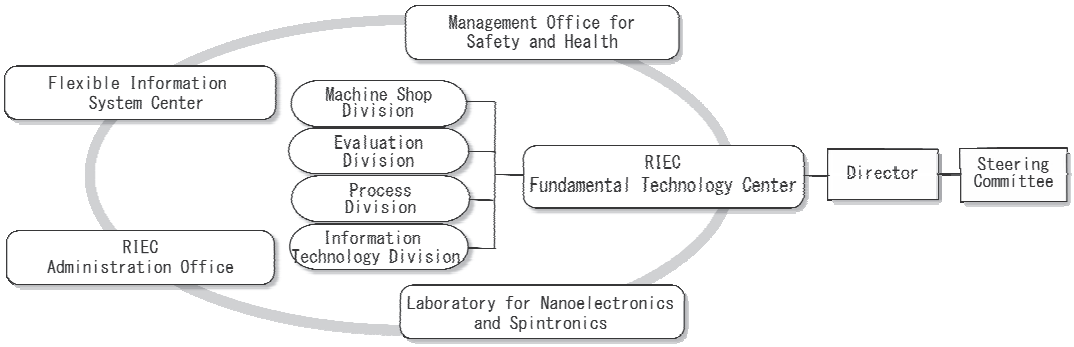
Fundamental Technology Center

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.

1. Machine Shop Division

The Machine Shop Division supplied machining products of 109, following requests from researchers. About 20 % of the requests were from the outside of the institute.

2. Evaluation Division

23 laboratories utilized evaluation and measurement apparatuses for shared usage (the utilization time was 7193 hours in total), and furthermore there was utilization from the outside of university. Glass processing products of 7 were supplied. 1878 litters of liquid nitrogen were supplied and technical assistance was provided in using liquid helium. This division also engaged in the maintenance of safety of the institute in cooperation with the administration office and the management office for safety and health.

3. Process Division

Electron-beam lithographic products of 263 were supplied in cooperation with the technical office, a section of Laboratory for Nanoelectronics and Spintronics. Technical supports were provided for operating the clean room of Laboratory for Nanoelectronics and Spintronics. Multi-layered thin films for optical usage were prepared by an electron beam evaporation technique.

4. Software Technology Division

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

[Staff]

Director (Professor): Yoichi UEHARA.

Assistant Professor: Nobuyuki SATO.

Technical Officials: Koichi SHOJI, Tamotsu SUENAGA, Kento ABE, Yasuaki MAEDA, Maho ABE, Takenori TANNO, Hiroyuki YAGYU, Iori MORITA, Rikima ONO, Michimasa MUSHA, Masahiko SATO, Yuko MARUYAMA, Kenji OHTA, Katsumi SAGAE, Fumitaka SAITO.

Ad-hoc research groups

Taking advantage of the wide range of expertise in the institute, ad-hoc research groups are formed outside of the formal organizational structure to investigate challenging exploratory topics and needs-based, cutting-edge subjects.

[Group of multimodal attention]

Selecting information obtained through sensory organs by attention is inevitable to live the complicated world with dynamic changes. A number of studies have investigated the mechanisms of attention, but most of them focused on cognitive processes. We have limited knowledge of attention effect on action. The present research investigates representation of space in the brain, which expresses the outside space based on multiple sensory information. We hypothesize that space attention in the multi-sensory representation is the process for selecting action. We started the investigation of attention in the multi-sensory space for audiovisual stimulation using a technique developed for visual attention.

[Next-Generation Nitride Electron Device Research Group]

The gallium nitride (GaN) material system is promising for power device applications such as microwave/millimeter-wave amplifiers and high-voltage switching for DC-AC inverters and DC-DC converters. Our goal is to establish advanced power devices with high-efficiency by means of the GaN-based materials by combining the technologies developed in the Institute for Materials Research and the Research Institute of Electrical Communication. For examples, nitrogen-polar GaN materials are intensively studied to apply them to high-electron mobility transistors for which gallium-polar materials are used in most of the conventional studies. By optimizing the crystal growth conditions, our group has realized GaN/AlGaN heterostructures with smooth surface. The transistor operation has also been confirmed by making devices using these crystals.

[Time salon：research group investigating the concept of time]

Time is one of most fundamental concepts created by human beings; through time constructing, we would obtain the ability to perceive the space, our bodies, and relationships to others. The ultimate goal of this research group is to discover the principles of human's time construction, and to develop a model of human cognition and control. To approach this goal, the group attempts to develop a model of time construction that underlies human perception through philosophical observation and scientific experimentation. In this academic year, we have held 11 discussion meetings, the "time salons", and have analyzed and discussed diverse topics related to human's time construction, ranging from Kant's transcendental deduction of time to recent findings in cognitive science and neural science, and have come up with some observations. We plan to continue the investigation in a wider perspective, consulting Nishida's theory of "basho" and others.

[Yotta Informatics Research Group]

The amount of information is rapidly increasing, which is projected to reach to the amount of one yotta bytes, one trillion times of one Tera-bytes, or 10 to 24th bytes. Ordinary extension technology of the conventional ICT cannot cope with such gigantic amount of information, therefore essential paradigm change for the information processing is indispensable. In this project, we aim at the new information science, which can manage the quality of information as well as the information amount. In 2016 five technical meetings with experts from industries were held every other month. An international symposium was also successfully held with three international invited speakers and some core members from the project.

[Cyber-Physical Security Research Group]

For the next-generation information and communication infrastructures such as IoT, M2M, and CPS, we aim to developing information security technologies to ensure security and reliability at the level of vast and diverse information sources (i.e., embedded devices such as sensor terminals) in a vertically integrated manner from the viewpoints of software constitutive theory, system security, hardware security, circuit architecture and next-generation microprocessor. This research group was established in November 2016. In this year, we discussed and confirmed our goal and approach for starting up this research group.

Center for Spintronics Integrated Systems (CSIS)

＜About the Center＞

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

Organization :

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

・Number of Staff : 27 (including 18 concurrent appointments)

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

○"Spintronics Integrated Circuit Project (project leader : Prof. Hideo Ohno)" in ImPACT program (program manager: Prof. Masashi Sahashi) of CSTI, 2014/10/2～

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

＜Major Achievements in 2016＞

(1) realization of sub-ns, field-free, low-current spin-orbit torque induced magnetization switching by improving configuration and material of a newly-developed device, (2) investigation of magnetization switching modes in elliptic magnetic tunnel junctions from the probability of switching induced by magnetic field or current pulses, (3) clarification of critical role of W deposition condition on spin-orbit torque induced magnetization switching of nanoscale W/CoFeB/MgO, (4) construction of a sophisticated design environment for MTJ-based LSI.

○"Research and Development of Spintronics Material and Device Science and Technology for a Disaster-Resistant Safe and Secure Society (principal investigator: Prof. Hideo Ohno)" under "R&D Project for ICT Key Technology" of MEXT, 2012/8/15～2017/3/31

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

＜Major Achievements in 2016＞

(1) achievement of the world-smallest magnetization switching energy of 6.3 fJ for a highly resistive magnetic tunnel junction by electric-field-induced switching, (2) demonstration of associative memory operation by artificial neural network with analog spintronics devices, (3) understanding of effect of electric-field-induced anisotropy modulation on current-induced magnetization switching from current-pulse width dependence of switching probability in nanoscale magnetic tunnel junction under in-plane magnetic field.

Research Organization of Electrical Communication (ROEC)

Towards Construction of Disaster-Resistant Information Communication Network

[Purpose of our establishment]

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

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

[Main Activities]

Since 2012, we have been promoting 12 disaster-resilient ICT projects supported by the Ministry of Internal Affairs and Communications. In 2016, one ongoing and two novel projects were promoted. We have also been engaged in a disaster information delivery project in Cross-ministerial Strategic Innovation Promotion Program (SIP) promoted by the Cabinet Office and a disaster management project supported by RISTEX, JST. In addition, we held workshop for Philippine citizen concerning our developed disaster-resilient ICT system. The research results produced by the promoted projects were presented at the Disaster Reconstruction and Regeneration Research Symposium of Tohoku University and Disaster-resilient ICT Research Symposium of NICT. Our activities were also described in ROEC Newsletters published in 2016.

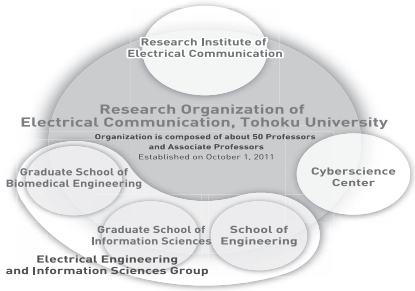


Fig.1 Research Organization of Electrical Communication.

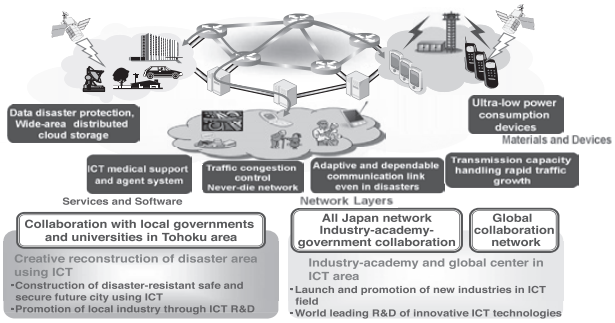


Fig.2 Overview of ICT Reconstruction Project.

[Staff]

Prof. Nei Kato (Executive Director)
Prof. Masayuki Kawamata (Vice Executive Director)
Specially Appointed Prof. Mitsukiro Shiozaki (Vice Executive Director)
Specially Appointed Prof. Katsumi Iwatsuki (Research Administrator)
Mr. Yasuharu Ito (Office Manager)
Mr. Syuichi Terashima (Manager)
Ms. Izumi Ishikawa (Secretary)

[Papers]

[1] Sho Takase, et al., "Modeling semantic compositionality of relational patterns", Engineering Applications of Artificial Intelligence, vol. 50, pp.256-264, April 2016.
[2] Toshikazu Sakano, et al., "Bringing Movable and Deployable Networks to Disaster Areas: Development and Field Test of MDRU," IEEE Network Magazine, vol. 30, no. 1, pp. 86-91, Jan.-Feb. 2016.
[3] T. Hirooka, et al., "Optical and wireless-integrated next-generation access network based on coherent technologies," Photonics West 2016, Invited talk, 9772-2, (2016).

Center for Innovative Integrated Electronic Systems (CIES)

＜Overview＞

Establishment: The CIES was established in October 2012 to enhance industry-academia collaborations and contribute to further development of the electronics industry. The building of the CIES was constructed in March 2013 as the first Science Park in this country by a private donation located in Aobayama New Campus at Tohoku University.

Organization: Director: Tetsuo Endoh (Professor, Graduate School of Engineering)
Number of staff: 64 (including appointments across RIEC, Graduate School of Engineering, Graduate School of Information Sciences, etc)

Mission: The CEIS researches and develops integrated electronic technologies with various research seeds that Tohoku University has and abundant results of industry-academia collaboration as centripetal force. And the CIES pursues to contribute to the enhancement of global competitiveness in the field of next generation integrated electronics systems by establishing an international industry-academia collaboration base. Further, the CIES aims for practical use of the technologies in this field and is aiming to create new industries.

Research topics: Research and development by industry-academia joint research projects, national research projects, community-based cooperation projects and so on, the CIES promotes the following research and development themes; 1) IT field centered on from next-generation semiconductor memory to electronic device components such as high-performance printed-circuit board, packaging, and image processing technologies, and 2) car-electronics field including electronic automotive components.

＜Major activities in FY2016＞

Although the CIES has managed the “CIES consortium” which consists of seven industry–academic collaborations, major national projects (JST-ACCEL, ImPACT and NEDO projects) and community-based cooperation projects in cooperation with various international and domestic companies from material to system aiming for the practical applications of innovative core technologies created by Tohoku University, we started new national projects by being adopted named as JST-OPERA and JSPS Core-to-Core Programs in this year.

In the development of spintronics integrated circuit, the CIES achieved world-class results by having developed multiple innovative technologies composed of next generation memories, high performance board and package technologies, image processing and so on, using world-first 300mm wafer process line and facilities which is compatible with world-class companies’ fabs. Especially, 2M STT-MRAM chip equipped with new memory cell array and nonvolatile neuron circuits have been successfully developed in R&D on spintronics integrated circuit, which contribute to the progresses of IoT and AI systems requiring ultralow power consumption. Therefore, we received the 14th Prime Minister's Award for its Contribution to Industry-Academia-Government Collaboration together with Tokyo Electron Ltd and Keysight Technologies International Japan G.K. with the appreciation of prior efforts

Companies participating in the CIES consortium have been increased steadily and the consortium has grown

into the world's largest one in this research field. Here, these companies utilized “a special private-sector investment promotion zone system (for information service-related industries)” under a joint application from Miyagi prefecture and local municipalities, and “financial assistance according to the amount of property tax paid (created under an agreement between Tohoku University and the city of Sendai)”. In addition, we promoted a technology matching program for regional and local companies with cooperation of Miyagi Prefecture, the Miyagi Advanced Electronics and Machinery Industry Association, the Miyagi Automotive Industry Promotion Council, the Tohoku Bureau of Economy, Trade and Industry and other partners, which resulted in a progress of commercialization and contributed to rebuild the Tohoku area and assist the region. In this fiscal year, Iwate Prefecture joined and cooperated with the program, which is a major achievement. Furthermore, the CIES internship program has been continued, which contributed to high-level human resources training for forging the future of this field.

Center for Spintronics Research Network (CSRN)

<Overview>

Establishment: April 1, 2016

Organization: Director: Hideo Ohno (Director, Professor, RIEC)
Number of academic members: 58 (including 2 full-time members and the other concurrent members from RIEC, IMR, IMRAM, Graduate School of Engineering, Graduate School of Science, WPI-AIMR, CIES, and FRIS, Tohoku University)

Mission: The center will be the hub of a network to promote collaborations with other research institutions within Japan and overseas, aiming to (1) improve competitiveness of world-leading spintronics research in Japan, (2) create new branches and enhance existing areas of industry, and (3) foster the next-generation human resources.

Research activities:
[Spintronics Device Creation Division]
We develop advanced systems and devices for energy creation and energy saving by using spintronics technology to provide eco-friendly infrastructure and to innovate conventional information and communication technology.
[Spintronics Device Characterization Division]
We develop advanced measurement techniques to characterize the behavior of spins in integrated spintronics devices. We also clarify the physical mechanism of the behavior of spins in spintronics devices theoretically to propose innovative spintronics devices.

<Major activities in FY2016>

・Cooperative Research Project

We adopt 36 cooperative research projects to promote collaborations with other spintronics researchers. The collaborators belong 34 institutions in Japan and 13 overseas institutions (in 10 countries). For detail, see the following URL: http://www.csrn.tohoku.ac.jp/

・Academic Meetings

The kick-off symposium of CSRN was held on May 24, 2016. For promoting exchange and fostering human resources of spintronics researchers, CSRN jointly hosted international conferences, workshops, and schools (13 meetings in total).

Leading Graduate Program “Interdepartmental Doctoral Degree Program for Multi-Dimensional Materials Science Leaders”

<Overview>

Establishment: October, 2013

Organization; Program manager: Kimio Hanawa (Executive Vice President for Education, Student Support and Student International Exchange)
Program coordinator: Tetsuya Nagasaka (Professor, Grad. School of Engineering)
Program members: about 60 academic staffs in Tohoku University

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

<Major activities in FY2016>

In FY2016, 12 new students joined the program and 51 students in total learned the fundamental and specialized subjects and joined long-term internship at domestic corporations and foreign institutions.

The 4th Student Meeting of Leading Graduate Schools was held during July 8-10, 2016 at Makuhari Messe International Conference Hall. Three students of the MD program attended the lectures presented by corporate executives at the meeting. They also exchanged their views and ideas with the attendee from other universities.

Graduate Program in Spintronics (GP-Spin)

<Overview>

Establishment: April 1, 2015

Organization: Program manager: Kimio Hanawa (Executive Vice President for Education, Student Support and Student International Exchange)
Program leader: Yoshiro Hirayama (Professor, Graduate School of Science)
Program members: 15 academic staffs in Tohoku University
Foreign organization: Johannes Gutenberg Univ. Mainz (Germany), Tech. Univ. München (Germany), Tech. Univ. Kaiserslautern (Germany), Univ. Regensburg (Germany), Tech. Univ. Delft (The Netherland), Univ. Groningen (The Netherland), Univ. Chicago (USA), Univ. New South Wales (Australia)

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

Activities: (1) Education by world-leading professors from all departments and institute in Tohoku University with participation from all over the world
(2) Joint education with foreign organization including joint supervised degree/joint degree, mutual visit and long-term internship, international school/workshop, qualifying examination to guarantee the educational quality

<Major activities in FY2016>

In FY2016, invited researchers including Prof. Peter Grünberg (Novel Prize Lauriate in Physics) visited Tohoku University from abroad and held the seminars for students of GP-Spin. They also had intensive discussions with students and researchers during their stay in Sendai.

The International Spintronics School co-sponsored by GP-Spin was held on August 31, 2016 in Tohoku University. World-leading 10 researchers in spintronics were invited as lecturers. They gave exciting lectures including the topics related to their new research results.

The ceremony commemorating the University-level agreement and MOU of jointly supervised Ph.D. between the University of Regensburg and Tohoku University was held on March 28, 2017. After that, Regensburg-Tohoku Workshop on Solid-State Physics and Spintronics was held during March 28-30, 2017 in Zao.

Yotta Informatics Research Center
Program for Key Interdisciplinary Research
Research platform for Yotta-scale data science

＜Project outline＞

Founded：October 2015

Organization：

Yotta Informatics Research Center (Project leader: Hiroaki Muraoka, RIEC, Professor)

Project members: 26 experts from eight departments.)

Purpose of the research:

Novel science and technology to manage both quantity and quality of yotta-scale information, in order to establish the future ICT technology and new humanics by collaborative work of engineering and human and social science

Research：

The amount of information is rapidly increasing, which is projected to reach to the amount of one yotta bytes, one trillion times of one Tera-bytes, or 10 to 24^{th} bytes. Ordinary extension technology of the conventional ICT cannot cope with such gigantic amount of information, therefore essential paradigm change for the information processing is indispensable. In this project, we aim at the new information science, which can manage the quality of information as well as the information amount. For the sake, experts of information engineering, human and social science from departments are discussing about interdisciplinary collaborating works to understand the quality and value of information, as well as the quantity. The value information is the key properties for the future informatics to receive the full benefit of the information in the upcoming “beyond the big data” era.

＜Major achievement in 2016＞

1. Meeting and discussions by the all project members
   The meetings were held every other month, or five times in total, to discuss about the information quality and value. Discussions with industry engineers were proactively carried out in order to explore the possibilities of research collaborations.
2. International symposium
   International symposium with invited talks by US and Japanese professors in terms of digital archaeology and media science was carried out.
3. Algorism of the information quality
   Analysis algorism is investigated so as to extract values from the large information based on its quality. The information processing is carried out by the human approach based on the objective measurable properties.

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, wireless communication, applications of ultrasonic communication and acoustic communication, non-linear physics and engineering, and computer software. On the basis of this rich historical background the Institute was designated as a 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."

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

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

The Project Selection Committee that includes members from 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 2016

Grant Number Title of Research	Principal Investigator	Research Collaborator of RIEC
H26／A01 Development of graphene-based electronics and photonic devices	**Takashi Uchino** Department of Electronics and Intelligent Systems, Faculty of Engineering, Tohoku Institute of Technology	**Taiichi Otsuji**
H26／A02 Measurement of polarization structure in layered piezoelectric thin films using scanning nonlinear dielectric microscopy	**Hiroyuki Odagawa** National Institute of Technology, Kumamoto College	**Yasuo Cho**
H26／A03 Fabrication of various type high-k/Ge structure by plasma processing and evaluation of their near-interface traps	**Hiroshi Okamoto** Graduate School of Science and Technology, Hirosaki University	**Michio Niwano**
H26／A04 Development of Fe_4N-based magnetic tunnel junctions with ferroelectric tunnel barrier	**Masakiyo Tsunoda** Graduate School of Engineering, Tohoku University	**Masafumi Shirai**
H26／A05 Studies on fabrication of ferromagnet/semiconductor hybrid structures and their application for spintronics devices	**Fumihiro Matsukura** Advanced Institute for Materials Research, Tohoku University	**Masafumi Shirai**
H26／A06 Highly-Strained and Atomically-Controlled Formation of Ge-Based Group-IV Semiconductors and Nanodevice Application	**Masao Sakuraba** Research Institute of Electrical Communication, Tohoku University	**Michio Niwano**
H26／A07 Structure-controlled synthesis and property elucidation of two-dimensional emiconductor material	**Toshiaki Kato** Department of Electronic Engineering, Tohoku University	**Satoshi Katano**
H26／A10 Development of Wireless Network Architecture for Dependable Air	**Suguru Kameda** Research Institute of Electrical Communication, Tohoku University	**Suguru Kameda**

Grant Number Title of Research	Principal Investigator	Research Collaborator of RIEC
H26／A11 Study on the organization of cortical circuits	**Shigeru Kubota** Graduate School of Science and Engineering, Yamagata University	**Michio Niwano**
H26／A12 Reconstruction of neuronal network for generation of hybrid brain	**Haruyuki Kamiya** Graduate School of Medicine, Hokkaido University	**Michio Niwano**
H26／A13 Dynamic cues for auditory space perception	**Akio Honda** Yamanashi Eiwa College	**Shuichi Sakamoto**
H26／A14 Speech intelligibility estimation without transmission characteristics under long-path echo conditions	**Yosuke Kobayashi** Computational Intelligence Unit, College of Information and Systems, Muroran Institute of Technology	**Shuichi Sakamoto**
H26／A15 Study on thin film functional device obtained by controlling normal magnetic field	**Tomoo Nakai** Industrial Technology Institute, Miyagi Prefectural Government	**Kazushi Ishiyama**
H26／A16 Development of nanostructured hybrid solar cells	**Yasuo Kimura** Tokyo University of Technology	**Teng Ma**
H26／A19 A study on new information processing technology focusing on the flow of information	**Keiichi Yasumoto** Graduate School of Information Science, Nara Institute of Science and Technology	**Gen Kitagata**
H26／A20 Study on Cooperative Mechanism of Sympathetic Devices for Mental Status Sharing	**Tatsuya Yamazaki** Graduate School of Science and Technology, Niigata University	**Hideyuki Takahashi**
H26／A21 An accurate estimation for acoustical transfer function of pinna from camera images	**Masashi Ito** Department of Electrical and Electronic Engineering, Tohoku Institute of Technology	**Shuichi Sakamoto**
H26／A23 Japan-Spain International Research Collaboration on Terahertz Sensing Devices	**MEZIANI Yahya Moubarak** University of Salamanca	**Taiichi Otsuji**

Grant Number Title of Research	Principal Investigator	Research Collaborator of RIEC
H26／A24 Study on Direct Digital RF MODEM Technologies	**Noriharu Suematsu** Research Institute of Electrical Communication, Tohoku University	**Noriharu Suematsu**
H26／A25 Cultural and individual differences in color lexicon	**Keiji Uchikawa** Tokyo Institute of Technology	**Satoshi Shioiri**
H26／A26 Machine Learning Hand-Manipulation for HCI	**Taku Komura** School of Informatics, University of Edinburgh	**Yoshifumi Kitamura**
H27／A01 Development of highly oriented oxide thin films for nano–electronic devices	**Kiyoshi Uchiyama** Department of Creative Engineering, National Institute of Technology, Tsuruoka College	**Yasuo Cho**
H27／A02 Basis Establishment of Plasma Nanobio-Medicine	**Toshiro Kaneko** Department of Electronic Engineering, Tohoku University	**Michio Niwano**
H27／A03 Quantum Heterostructure Formation of Group-IV Semiconductors and Control of Electronic Properties Utilizing Atomically-Controlled Plasma CVD	**Masao Sakuraba** Research Institute of Electrical Communication, Tohoku University	**Michio Niwano**
H27／A04 Operando spectromicroscopy for next-generation devices researches	**Hirokazu Fukidome** Research Institute of Electrical Communication, Tohoku University	**Hirokazu Fukidome**
H27／A05 Development of novel quantum light source for quantum info-communication	**Keiichi Edamatsu** Research Institute of Electrical Communication, Tohoku University	**Keiichi Edamatsu**
H27／A06 Nano-scale Geometrical Control and Optical Properties of a Single Metal Nanostructure	**Satoshi Katano** Research Institute of Electrical Communication, Tohoku University	**Satoshi Katano**
H27／A07 Computational Study of Plasmons in Semiconductor Two-Dimensional Electron Systems for THz Device Applications	**Koichi Narahara** Department of Electrical and Electronic Engineering, Kanagawa Institute of Technology	**Akira Satou**

Grant Number Title of Research	Principal Investigator	Research Collaborator of RIEC
H27／A08 Studies on resonant tunneling THz signal generators having low phase noise properties	Koichi Maezawa Graduate School of Science and Engineering, University of Toyama	Taiichi Otsuji
H27／A09 A study of carrier conversion system between optical and wireless signal frequency domain for future full-coherent access networks	Naoto Yoshimoto Chitose Institute of Science and Technology	Taiichi Otsuji
H27／A10 A research on reflectarray using metamaterial for propagation improvement in M2M communication	Tamami Maruyama National Institute of Technology, Hakodate College	Noriharu Suematsu
H27／A11 An Empirical Study on SDN-based Networking System based on Changes in User's Physiological Indexes	Masaki Omata University of Yamanashi	Gen Kitagata
H27／A12 Effects of self-movements on perception of the surrounding world	Wataru Teramoto Cognitive Psychology Lab., Kumamoto University	Shuichi Sakamoto
H27／A13 Studies on relationship between perception of monaural sound and head-related transfer function	Daisuke Morikawa Japan Advanced Institute of Science and Technology	Shuichi Sakamoto
H27／A14 Construction of functional bio-information devices via combination of silicon microfabrication and lipid bilayers	Ayumi Hirano Graduate School of Biomedical Engineering, Tohoku University	Michio Niwano
H27／A16 Workshop and Practical Study on the Handing Down of Disaster Experiences from the Perspective of Information Communication Technology	Shosuke Sato International Research Institute of Disaster Science, Tohoku University	Jorge Trevino
H27／A17 Influence of synchrony perception on sense of presence and verisimilitude in multimodal environment	Tomoko Ohtani Art Media Center, Tokyo University of the Arts	Jorge Trevino
H27／A18 Influence of speaker's movie of speech utterance on serial recall task	Tomoko Ohtani Art Media Center, Tokyo University of the Arts	Shuichi Sakamoto

Grant Number Title of Research	Principal Investigator	Research Collaborator of RIEC
H27／A19 Development of physical index for speech intelligibility considering long path echo	Hayato Sato Departments of Architecture, Graduate School of Engineering, Kobe University	Yôiti Suzuki
H27／A20 Research on measurement technologies of earthquakes, tsunami, and crustal deformation using an optical-fiber network	Akito Araya Earthquake Research Institute, The University of Tokyo	Masataka Nakazawa
H27／A21 Hardware Technology for Brain Computation	Shigeo Sato Research Institute of Electrical Communication, Tohoku University	Shigeo Sato
H27／A23 Research of Multimodal Agent Framework for Symbiotic Computing	Takahiro Uchiya Nagoya Institute of Technology	Tetsuo Kinoshita
H27／A24 Study on knowledge acquisition and utilization for the diversifying information networks	Akinori Takahashi Graduate School of Engineering Science, Akita University	Tetsuo Kinoshita
H27／A25 Development of a system architecture and infrastructure technology for the Smart Community	Akira Fukuda Kyusyu University	Tetsuo Kinoshita
H27／A26 Empirical Researches for introducing ubiquitous systems into the actual life	Yutaka Arakawa Graduate School of Information Science, Nara Institute of Science and Technology	Hideyuki Takahashi
H27／A27 Research on olfactory multimodal information processes in humans	Nobuyuki Sakai Graduate School of Arts and Letters, Tohoku University	Shuichi Sakamoto
H28／A01 Exploration of phase change phenomena of nanometer-scale materials and their applications to opto-electronic devices	Masashi Kuwahara National Institute of Advanced Industrial Science and Technology	Yoichi Uehara

Grant Number Title of Research	Principal Investigator	Research Collaborator of RIEC
H28／A02 Study on High Power Amplifier with InGaAs HEMTs with Field Plate	**Yohtaro Umeda** Department of Electrical Engineering, Faculty of Science and Technology, Tokyo University of Science	**Tetsuya Suemitsu**
H28／A03 Electroluminescence from Si-Ge based Quantum Dots	**Seiichi Miyazaki** Graduate School of Engineering, Nagoya University	**Michio Niwano**
H28／A04 Improvement of Superconducting Detectors and Readouts	**Hirokazu Ishino** Graduate School of Natural Science and Technology, Okayama University	**Shigeo Sato**
H28／A05 Study on a local field effect of localized electronic polarizations in semiconductors	**Yasuyoshi Mitsumori** Research Institute of Electrical Communication, Tohoku University	**Yasuyoshi Mitsumori**
H28／A06 Quantum emitters coupled to a chiral nanowaveguide	**Mark Sadgrove** Research Institute of Electrical Communication, Tohoku University	**Mark Sadgrove**
H28／A07 A study on objective measure for speech articulation and intelligibility	**Masato Akagi** Graduate School of Advanced Science and Technology, Japan Advanced Institute of Science and Technology	**Yôiti Suzuki**
H28／A08 Study on the Architecture of Brainware System	**Toshiyuki Kanoh** Central Research Laboratories, NEC Corporation	**Takahiro Hanyu**
H28／A09 Facilitation Interface Using Snacks for Promotion of Creativity	**Ryoko Ueoka** Faculty of Design, Kyushu University	**Kazuki Takashima**
H28／A10 Development of a sound source segregation system based on artificial intelligence technology	**Kenji Ozawa** Integrated Graduate School of Medicine, Engineering, and Agricultural Sciences, University of Yamanashi	**Yôiti Suzuki**
H28／A11 Communication system for controlling human cognition and behavior from kansei information of speech	**Akihiro Tanaka** Tokyo Woman's Christian University	**Shuichi Sakamoto**

Grant Number Title of Research	Principal Investigator	Research Collaborator of RIEC
H28／A13 Study of the cooperative environment for building visual cognition models	Ko Sakai Faculty of Engineering, Information and Systems, University of Tsukuba	Satoshi Shioiri
H28／A14 Joint demonstrations of a platform to validate, evaluate and reflect fault and disaster tolerances of wide area distributed systems	Hiroki Kashiwazaki Osaka University	Takaki Nakamura
H28／A15 Japan-USA International Collaborative Research on Graphene-Based tomically-Thin 2D Heterostructures and their Terahertz Applications	MITIN Vladimir Department of Electrical Engineering, University at Buffalo, SUNY	Taiichi Otsuji
H28／A16 Electrically controlled magnetization and spin dynamics by spin orbit interaction	Makoto Kohda Department of Materials Science, Tohoku University	Shun Kanai
H28／A17 Inducing techniques for magnetic anisotropy of amorphous magnetostrictive films using inverse-magnetostriction effect and its applications	Shuichiro Hashi Research Institute of Electrical Communication, Tohoku University	Shuichiro Hashi
H28／A18 A study on fast magnetization reversal by electrical means in nano-scale spintronics devices	Hideo Sato Center for Spintronics Research Network, Tohoku University	Shunsuke Fukami
H28／A19 A study on magnetization reversal of nano-scale ferromagnet	Hideo Sato Center for Spintronics Research Network, Tohoku University	Shunsuke Fukami
H28／A20 Display technology for high dynamic range images using a stochastic dithering method	Takehiro Nagai Department of Informatics, Graduate School of Science and Engineering, Yamagata University	Ichiro Kuriki
H28／A21 Application of 3D Interactive Technologies to Everyday Gesture-based Human-Computer Interaction based on Design Methodology	Yoshifumi Kitamura Research Institute of Electrical Communication, Tohoku University	Yoshifumi Kitamura

Grant Number Title of Research	Principal Investigator	Research Collaborator of RIEC
H28／A22 Reproduction of ultra-realistic space using ultra-high definition Omni-direction image and sound	Masami Okyudo Faculty of Tourism, Wakayama University	Yôiti Suzuki
H28／A23 Detection and Prediction of Abnormal State from Time-series Data	Goutam Chakraborty Faculty of Software and Information Science, Iwate Prefectural University	Tetsuo Kinoshita
H28／A24 Intelligent Network Security Technologies for Next-Generation IoT Platform	Shinobu Nagayama Department of Computer and Network Engineering, Hiroshima City University	Masanori Natsui
H26／B01 Study of functional piezoelectric materials and applications to advanced communication devices	Shin-ichiro Umemura Graduate School of Biomedical Engineering, Tohoku University	Yôiti Suzuki
H26／B02 Research on the new concept devices with integration of nano materials on silicon technology	Heiji Watanabe Graduate School of Engineering, Osaka University	Hideo Ohno
H26／B03 Research for future electronic systems by nano devices and circuits with nano semiconductor materials	Kikuo Yamabe Graduate School of Pure and Applied Sciences, University of Tsukuba	Hideo Ohno
H26／B05 Hybrid Semiconductor Circuit Technologies and Their Applications for Next Generation RFICs	Kenjiro Nishikawa Kagoshima University	Noriharu Suematsu
H26／B06 Advanced Communication and Measurement Systems Using Coherent Multicarrier Lightwave	Hidemi Tsuchida National Institute of Advanced Industrial Science and Technology	Masataka Nakazawa
H26／B07 Kotology: Rethinking and Recreating Biomimetics	Koichi Oosuka Department of Mechanical Engineering, Osaka University	Akio Ishiguro
H26／B08 Contribution of self-body motion to multisensory integration	Kenzo Sakurai Department of Human Science, Tohoku Gakuin University	Yôiti Suzuki

Grant Number Title of Research	Principal Investigator	Research Collaborator of RIEC
H26／B09 International Research Collaboration of Brainware LSI	**Takahiro Hanyu** Research Institute of Electrical Communication, Tohoku University	**Takahiro Hanyu**
H26／B10 Reliable and Scalable Foundation for Parallel Computing on Many-Core Architecture	**Kazuhiko Kato** Faculty of Engineering, Information and Systems, University of Tsukuba	**Atsushi Ohori**
H26／B11 Sensing and Communication Technologies for Human and Mobility	**Takeshi Oishi** Institute of Industrial Science, The University of Tokyo	**Kazuki Takashima**
H27／B01 Finding innovative reactive fields related with multi-scale structures in various plasma flows	**Akira Ando** Graduate School of Engineering, Tohoku University	**Maki Suemitsu**
H27／B02 Material synthesizing for developing new applications using SiC hetero-structure	**Maki Suemitsu** Research Institute of Electrical Communication, Tohoku University	**Maki Suemitsu**
H27／B03 Physics of quantum measurement and communication	**Keiichi Edamatsu** Research Institute of Electrical Communication, Tohoku University	**Keiichi Edamatsu**
H27／B04 Physics and applications of spin dynamics in solids	**Fumihiro Matsukura** Advanced Institute for Materials Research, Tohoku University	**Shun Kanai**
H27／B05 Evaluation of telecommunication handset performance under the influence of broadband unnecessary radio wave	**Masahiro Yamaguchi** Graduate School of Engineering, Tohoku University	**Kazushi Ishiyama**
H27／B06 Science Education Harmonized with Objectivity and Humanity -For the Issues of Modern Science and Future of Mankind-	**Ichiro Tsuda** Faculty of Science, Hokkaido University	**Hideo Ohno**
H27／B07 Parallel processes of brain functions	**Ken-Ichiro Tsutsui** Life Sciences Division of Systems Neuroscience, Tohoku University	**Satoshi Shioiri**

Grant Number Title of Research	Principal Investigator	Research Collaborator of RIEC
H27／B08 Optimization of Information Representation on a High-Dimensional Neural Network	Akira Hirose The University of Tokyo	Shigeo Sato
H27／B09 Functionalization of oxide surfaces and its application to nanodevices	Fumihiko Hirose Graduate School of Science and Engineering, Yamagata University	Michio Niwano
H27／B12 Preliminary examination for analysis of asynchronous in network dynamics	Kohei Sonoda Research Organization of Science and Technology, Ritsumeikan University	Kazuto Sasai
H27／B13 Studies on enrichment of media technologies	Naofumi Aoki Graduate School of Information Science and Technology, Hokkaido University	Yôiti Suzuki
H28／B01 Precise Solid State Science and its Device Applications via Controlling Charge and Spin of Electrons	Kensuke Kobayashi Department of Physics, Graduate School of Science, Osaka University	Hideo Ohno
H28／B02 Research in magnetic materials and magnetic devices with high performance for advanced communication equipment	Ken-ichi Yamamoto Faculty of Engineering, University of the Ryukyus	Kazushi Ishiyama
H28／B03 Various media of particle-fluid hybrid system with charging effects and their potential functions	Osamu Sakai Department of Electronic Systems Engineering, The University of Shiga Prefecture	Michio Niwano
H28／B04 Visual mechanisms for SHITSUKAN perception	Katsunori Okajima Yokohama National University	Ichiro Kuriki
H28／B05 A Study for Persons, Space, and Information Technologies	Yoshifumi Kitamura Research Institute of Electrical Communication, Tohoku University	Yoshifumi Kitamura
H28／B06 Logical Approach to Formalization of Mathematics	Takafumi Sakurai Department of Mathematics and Informatics, Graduate School of Science, Chiba University	Yoshihito Toyama

Grant Number Title of Research	Principal Investigator	Research Collaborator of RIEC
H28／B07 Technical fusion of industrial programming language development and academic research on programming languages	**Yukihiro Matsumoto** Ruby Association	**Katsuhiro Ueno**
H28／B08 Application study of Microwave and Laser Aided Synthetic Aperture Radar	**Yuichiro Kogi** Faculty of Engineering, Fukuoka Institute for Technology	**Hiroshi Yasaka**
H28／B09 Constructing next-generation academic community that applies human-computer interaction researches	**Daisuke Sakamoto** Hokkaido University	**Yoshifumi Kitamura**
H28／B10 Magnetic Field Measurement System using Magneto-optical Effect	**Kazushi Ishiyama** Research Institute of Electrical Communication, Tohoku University	**Kazushi Ishiyama**
H28／B11 Development of HCI Research Activities in Asia	**Yoshifumi Kitamura** Research Institute of Electrical Communication, Tohoku University	**Yoshifumi Kitamura**
H28／B12 Study on mechanisms of visual processing with eye movements	**Kazumichi Matsumiya** Research Institute of Electrical Communication, Tohoku University	**Kazumichi Matsumiya**
H28／B13 Novel device applying chemical sensors for multi-parameter measurement	**Ko-ichiro Miyamoto** School of Engineering, Tohoku University	**Michio Niwano**
H28／B14 Research on information quality and value	**Hiroaki Muraoka** Research Institute of Electrical Communication, Tohoku University	**Hiroaki Muraoka**
H28／B15 Research and development of multipurpose micro gimbal and its applications	**Koh Sueda** National University of Singapore	**Yoshifumi Kitamura**
H28／B16 Interactive Visualization of Big data on Socio-economic data	**Miki Miyaki** College of Business, Rikkyo University	**Kazuki Takashima**

Grant Number Title of Research	Principal Investigator	Research Collaborator of RIEC
H26／S1 Project to construct the basis for future science and technology of conferment wave	Hidenori Mimura Research Institute of Electronics, Shizuoka University	Hiroshi Yasaka
H26／S2 Spintronics Academic Alliance	Masaaki Tanaka Center for Spintronics Research Network (CSRN), Department of Electrical Engineering & Information Systems, The University of Tokyo	Masafumi Shirai
H26／S3 Collaborative Research on Nano-electronics	Katsuyuki Utaka Faculty of Science and Engineering, Waseda University	Michio Niwano
H27／S1 Empathic Computing System through interactive knowledge emergence based on massive data processing	Kazunori Komatani The Institute of Scientific and Industrial Research, Osaka University	Yoshifumi Kitamura

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

	Title	Date
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 ⅣSemiconductor 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

	Title	Date
29	The 4th RIEC International Workshop on Spintronics	Oct.9-10,2008
30	Global Symposium on Millimeter Waves 2009 (GSMM2009)	Apr.20-22,2009
31	Mini R.I.E.C. workshop on multimodal perception	Apr.24,2009
32	The 4th International Symposium on Ultrafast Photonic Technologies	Aug.4-5,2009
33	PIMRC2009 Personal Indoor and Mobile Radio Communications Symposium 2009	Sep.13-16,2009
34	2nd RIEC-CNSI Workshop on Nanoelectronics,Spintronics and Photonics (5th RIEC Symposium on Spintronics)	Oct.22-23,2009
35	International Workshop on the principles and applications of spatial hearing 2009 (IWPASH2009)	Nov.11-13,2009
36	5th International Workshop on New Group IV Semiconductor Nanoelectronics	Jan.29-30,2010
37	6th RIEC International on Spintronics	Feb.5-6,2010
38	2nd International Workshop on Nanostructure & Nanoelectronics	Mar.11-12,2010
39	2nd RIEC International Symposium on Graphene Devices (ISGD2010)	Oct.27-29,2010
40	9th Japan-Korea Symposium on Surface Nanostructures	Nov.15-16,2010
41	The 7th RIEC International Workshop on Spintronics	Feb.3-4,2011
42	The 42nd RIEC International Symposium 12th International Multisensory Research Forum (IMRF2011)	Oct.17-20,2011
43	The 8th RIEC International Workshop on Spintronics	Feb.2-3,2012
44	The Sixth International Symposium on Medical, Bio- and Nano-Electronics	Mar.8,2012
45	3rd International Workshop on Nanostructures & Nanoelectronics	Mar.21-22,2012
46	9th RIEC International Workshop on Spintronics	May 31-Jun.2,2012
47	The 1st International Workshop on Smart Technologies for Energy, Information and Communication (STEIC2012)	Oct.18-19,2012
48	Technical University of Dresden and Tohoku University Symposium 2012	Nov.2,2012
49	The 1st RIEC International Symposium on Brain Functions and Brain Computer	Nov.15-16,2012
50	Tohoku – Harvard Joint Workshop New Directions in Materials for anoelectronics,Spintronics and Photonics （10th RIEC International Workshop on Spintronics）	Jan.15-16,2013
51	11th RIEC International Workshop on Spintronics & 3rdCSISInternationalSymposiumonSpintronics-based VLSIs	Jan.31-Feb.1,2013
52	7th International Symposium on Medical, Bio- and Nano-Electronics	Mar.7,2013
53	6th Global　Symposium on Millimeter Wave 2013	Apr.22-23,2013
54	The 2nd RIEC International Symposium on Brain Functions and Brain Computer	Feb.21-22,2014
55	8th International Symposium on Medical,Bio- and Nano-Electro	Mar.6-7,2014

	Title	Date
56	5th International Workshop on Nanostructures and Nanoelectronics	Mar.6-7,2014
57	12th RIEC International Workshop on Spintronics	Jun.25-27,2014
58	The IEEE International Conference on Microwave Magnetics	Jun.29-Jul.2,2014
59	RIEC International Symposium on Perception and Communication	Jul.24,2014
60	APMC 2014(2014 Asia-Pacific Microwave Conference)	Nov.4-7,2014
61	The 3rd RIEC International Symposium on Brain Functions and Brain Computer	Feb.18-19,2015
62	International Symposium on Brainware LSI	Mar.2-3,2015
63	The 9th International Symposium on Medical, Bio- and Nano-Electronics	Mar.2-4,2015
64	The 6th International Workshop on Nanostructures and Nanoelectronics	Mar.2-4,2015
65	RIEC International Symposium on Vision and Cognition	Mar.20,2015
66	The 23rd Symposium of the International Colour Vision Society (ICVS 2015)	Jul. 3-7, 2015
67	RIEC International Symposium on Computer Graphics and Interactive Techniques: New Horizon	Sep. 26-27,2015
68	13th RIEC International Workshop on Spintronics	Nov. 18-20,2015
69	The 4th RIEC International Symposium on Brain Functions and Brain Computer	Feb. 23-24,2016
70	International Symposium on Brainware LSI	Feb. 26-27,2016
71	The 10th International Symposium on Medical, Bio- and Nano-Electronics	Mar. 1-3,2016
72	The 7th International Workshop on Nanostructures and Nanoelectronic	Mar. 1-3,2016
73	RIEC International Symposium on Ultra-Realistic Interactive Acoustic Communications 2016	May 20-21,2016
74	RJUSE TeraTech-2016: The 5th Russia-Japan-USA-Europe Symposium on Fundamental & Applied Problems of Terahertz Devices & Technologies (RIEC International Symposium on Fundamental & Applied Problems of Terahertz Devices & Technologies)	Oct.31-Nov.4,2016
75	Dependable Wireless Workshop 2016	Nov.9-10,2016
76	14th RIEC International Workshop on Spintronics	Nov.17-19,2016
77	The 4th RIEC International Symposium on Brainware LSI	Feb. 24-25,2017
78	The 5th RIEC International Symposium on Brain Functions and Brain Computer	Feb. 27-28,2017
79	RIEC International Workshop on Biomedical Optics 2017	Mar. 6,2017
80	The 8th RIEC International Workshop on Nanostructures and Nanoelectronics	Mar. 6-7,2017

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, Group of ECEI (Electrical Engineering, Communication Engineering, Electronic Engineering, and Information Engineering) in Graduate Schools of Engineering, Information Sciences, Biomedical Engineering, related scientists and engineers inside and outside Tohoku University. The Study Groups on Electrical Communication consist of 15 Sub-Groups as listed, to deal with specific subjects. Each Sub-Group holds workshops and 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 the General Chairman or each Sub-Group Chairman for general information or more specific questions.

Electromagnetic and Optical Waves Engineering	
Chair	Prof. Yuji Matsuura
Manager	Associate Prof. Takashi Katagiri

Acoustic Engineering	
Chair	Prof. Yôiti Suzuki
Manager	Associate Prof. Shuichi Sakamoto
Manager	Lecturer Takashi Nose

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

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

Computer Science	
Chair	Prof. Eijiro Sumii
Manager	Associate Prof. Kazutaka Matsuda

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

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

Spinics	
Chair	Prof. Shin Saito
Manager	Prof. Kenji Nakamura
Manager	Associate Prof. Shuichiro Hashi

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

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

Brainware	
Chair	Prof. Akio Ishiguro
Manager	Associate Prof. Takeshi Kano

Mathematical Physics and its Application to Information Sciences	
Chair	Prof. Kazuyuki Tanaka
Manager	Assistant Prof. Shun Kataoka

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

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

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

7. International Activities

Many of the staff in RIEC contribute to the development of technology and science in the world by serving as editors of referees of international journals or by chairing or programming international conferences. In some fields in electronics, electrical communications, or information engineering RIEC serves as a Center of Excellence (COE), which attracts 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

- Institute of Physics, Polish Academy of Sciences (Poland)
- ＊The James Frank Institute, The University of Chicago (U.S.A.)
- ＊The Faculty of Science, Chulalongkorm University (Thailand)
- ＊Harbin Institute of Technology (China)
- ＊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)
- IHP-Innovations for High Performance Microelectronics (Germany)
- Interdisciplinary Center on Nanoscience of Marseille, National Center of Scientific Research (France)
- Institute of Semiconductors, Chinese Academy of Sciences (China)
- WINLAB, Rutgers University (U.S.A.)
- University of Vigo (Spain)
- State University of New Nork, College of Nanoscale Science and Engineering (U.S.A)
- Department of Physics, National Sun Yat-Sen Univesity (Taiwan)
- Research and Educational Center “Photonics and Infrared Technology” and Institute of Radio Electronics and Laser Technology , Bauman Moscow State Technical University (Russia)
- Research Laboratory of Electronics and Microsystems Technology Laboratories, Massachusetts Institute of Technology (U.S.A.)
- St. Petersburg Electrotechnical University (Russia)

（＊: expired program)

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

1	Acoustical Science & Technology
2	Applied Acoustics
3	IEEE Magnetics Letter
4	IEICE Electronics Express
5	IEICE Transactions on Information and Systems
6	International Journal of Artificial Intelligence, Neural Networks, and Complex Problem Solving Technologies
7	International Journal of Computer Science and Network Security
8	International Journal of Distributed Sensor Networks
9	International Journal of Energy, Information and Communications

10	International Journal of Information Sciences and Computer Engineering (IJISCE)
11	Japanese Journal of Applied Physics
12	Journal of Cryptographic Engineering
13	Journal of information hiding and multimedia signal processing
14	Journal of Magnetics, Korean Magnetics Society
15	Journal of SPIN
16	Mobile Information Systems
17	Nature Communications
18	Neural Networks
19	Nonlinear Theory and Its Applications, IEICE
20	NPG Asia Materials
21	Optical Fiber Technology
22	Optical Review
23	Optics Communications
24	Scientific Reports
25	SOFT ROBOTICS

Recent international conferences programmed by a staff in RIEC

1	14th RIEC International Workshop on Spintronics
2	16th Smart Card Research and Advanced Application Conference
3	33rd International Conference on the Physics of Semiconductors (ICPS)
4	62nd Annual Conference on Magnetism and Magnetic Materials (MMM 2017)
5	9th International Conference on Physics and Applications of Spin-related Phenomena in Solids (PASPS-IX)
6	9th International Symposium on Metallic Multilayers (MML2016)
7	ACM SIGCHI
8	ACM SIGGRAPH
9	ACM Symposium on Satial User Interfaces (SUI 2016)
10	ACM Symposium on User Interface Software and Technology
11	ACM Symposium on Virtual Reality Software and Technology (VRST)
12	ACM UIST 2016
13	ACSIN14 & ICSPM26
14	Asian-Pacific Conference on Vision 2017
15	Asia-Pacific Microwave Conference (APMC)
16	Asia-Pacific Workshop on Fundamentals and Applications of Advanced Semiconductor Devices (AWAD)
17	Eurographics Workshop on Virtual Environment (EGVE)
18	European Conference on Optical Communication (ECOC)
19	European Solid-State Device Research Conference (ESSDERC)
20	Human-Computer Interaction (TC-13)
21	IEEE International Symposium on Multiple-Valued Logic
22	IEEE Magnetics Society Summer School
23	IEEE NEMS 2016
24	IEEE Symposium on 3D User Interfaces (3DUI 2016)
25	IEEE Symposium on 3D User Interfaces (3DUI 2017)
26	Int. Conf. on Micro- and Nano-Electronics (ICMNE)

27	International Conference on Artificial Reality and Tele-existence (ICAT)
28	International Conference on Cryptographic Hardware and Embedded Systems
29	International Conference on Electron Dynamics in Semiconductors, Optoelectronics and Nanostructures (EDISON)
30	International Conference on Indium Phosphide and Related Materials (IPRM)
31	International Conference on Modern Materials & Technologies (CIMTEC)
32	International Conference on Nanophotonics and Micro/Nano Optics (NANOP)
33	International Conference on Recent Progress in Graphene Research (RPGR)
34	International Conferences on Modern Materials & Technologies (CIMTEC)
35	International Federation for Information Processing (IFIP)
36	International Symposium on Adaptive Motion of Animals and Machines
37	International Symposium on Compound Semiconductors (ISCS)
38	International Symposium on Frontiers in THz Technology (FTT)
39	International Symposium on Infra-Red, Milli-Meter-Wave, and Terahertz (IRMMW-THz)
40	International Workshop on Constructive Side-Channel Analysis and Secure Design
41	International Workshop on Security Proofs for Embedded Systems
42	International Workshop on Synthesis And System Integration of Mixed Information technologies
43	Optical Fiber Communication conference (OFC)
44	Optical nanofiber application (ONNA2017)
45	Russia-Japan-USA-Europe Symposium on Fundamental & Applied Problems of Terahertz Devices & Technologies (RJUSE)
46	Soft Magnetic Materials Conference
47	SPIE International Conference on Defense, Commercial, and Sensing
48	Technical Committee of Multiple-Valued Logic, IEEE Computer Society
49	The 28th Magnetic Recording Conterence (TMRC2017)
50	The 31st IEEE International Conference on Advanced Information Networking and Applications (AINA-2017)
51	The 3rd International Symposium on Intelligent Systems Technologies and Applications (ISTA'17)
52	The International Multisensory Research Forum 2017 (IMRF2017)
53	The Twelfth International Conference on Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP2016)
54	Topical Workshop on Heterostructure Microelectronics (TWHM)
55	VLSI Circuits Symposium

8. Periodicals Published by the Institute

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

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

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

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

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

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

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

3. RIEC News

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

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

research and the vision of the future from RIEC's contributions to the progression of science and technology in Japan. RIEC News was first launched in March 2011, In fiscal year 2016, 17th, 18th and 19th issues were published. Every issue introduces special topics such as large scale projects and Specially-Promoted Research, etc. RIEC News also includes current information about each laboratory and center, all kinds of RIEC events, research exchange meetings, laboratories open to the public (RIEC Open Day), etc. English version is also published in March 2014. Further, RIEC News offers a notification service by mail whenever a new issue is released and an electronic version of every issue published so far can be downloaded by following the link below.

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

9. Staff, Budget

1. Faculty&Staff

as of May 1, 2016

Professors	23
Associate Professors	19
Assistant Professors	23
Research Fellows	9
Specially Appointed Professors	1
Specially Appointed Assistant Professors	1
Administrative Staff	15
Technical Staff	13
Total	104

2. Researchers (FY2016)

Foreign Researchers	Visiting Professors	7
	Visiting Asociate Professors	1
Cooperative Researchers of Private Company etc		2
JSPS Research Fellowship for Young Scientists		10
JSPS Postdoctral Fellowship for Overseas Researchers		1
Invitation Fellowship for Research in Japan		1
Contract Researchers		8
Contract Trainees		1
Total		31

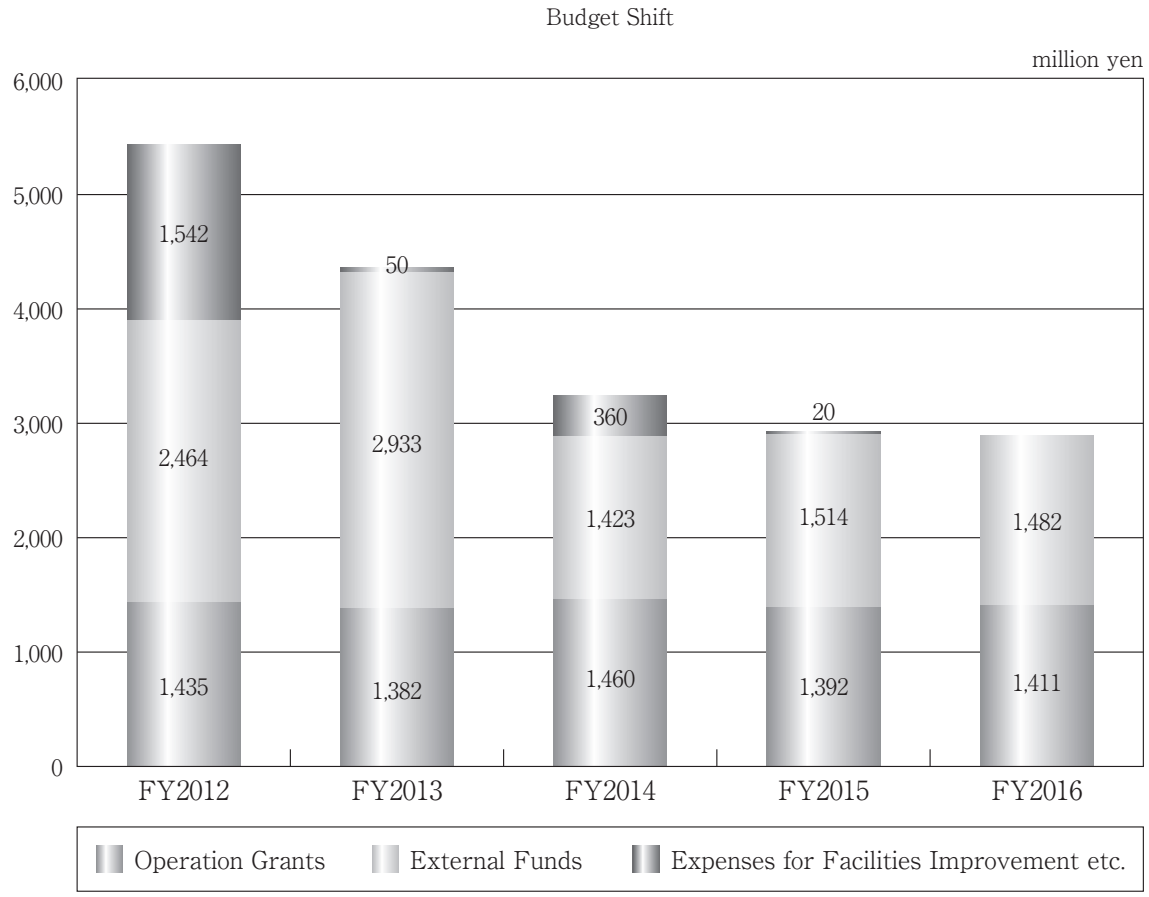
3. Students

as of May 1, 2016

	School of Engineering	Graduate School of Information Science	Graduate school of Biomedical Engineering	RIEC	Total
Undergraduate Students	51				51
Master Course Students	90 (9)	42 (6)	5		137 (15)
Doctor Course Students	28 (7)	10 (4)	1 (1)		39 (12)
Institute Research Students				1	1
Total	169 (16)	52 (10)	6 (1)	1	228 (27)

※ ( ) Foreigner

4. Budget



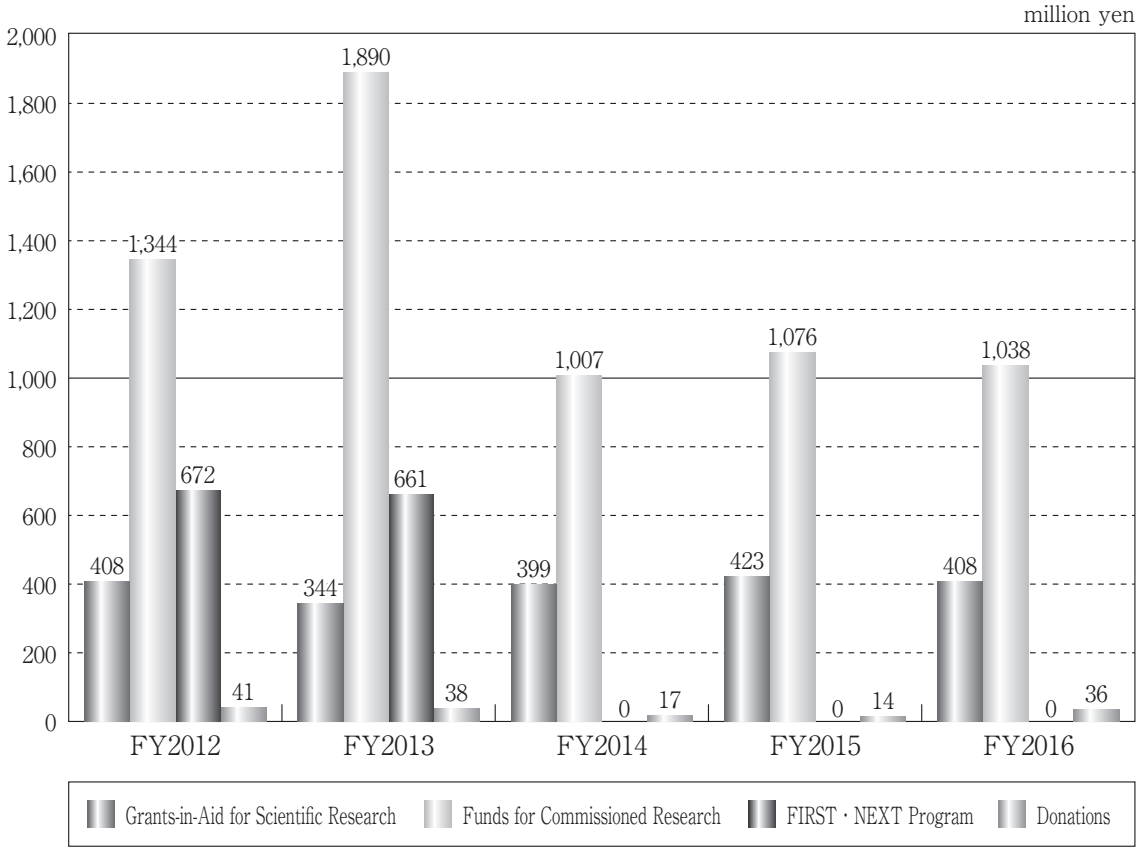
Budget Summary

thousand yen

Categories		FY2012	FY2013	FY2014	FY2015	FY2016
Operation Grants	Personnel Expenses	770,443	723,507	791,174	724,798	804,575
	Non-Personnel Expenses	665,038	658,590	668,941	667,582	606,599
Operation Grants Total		1,435,481	1,382,097	1,460,115	1,392,380	1,411,174
External Funds	Grants-in-Aid for Scientific Research	407,629	343,824	399,311	422,846	407,902
	Funds for Commissioned Research	1,344,071	1,890,012	1,007,060	1,076,220	1,037,842
	FIRST Program ※1・NEXT Program ※2	671,668	660,578	0	0	0
	Donations	40,714	38,100	16,890	14,490	36,190
	Indirect Expenses	326,869	336,037	212,669	219,886	247,452
External Funds Total		2,464,082	2,932,514	1,423,261	1,513,556	1,481,934
Expenses for Reconstruction		4,993	0	0	0	0
Expenses for Relocation		0	49,632	359,770	20,011	0
Expenses for Facilities Improvement		1,536,530	0	0	0	0
Expenses for Facilities Improvement etc. Total		1,541,523	49,632	359,770	20,011	0
Total		5,441,086	4,364,243	3,243,146	2,925,947	2,893,108

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

External Funds



External Funds thousand yen

Categories	FY2012	FY2013	FY2014	FY2015	FY2016
Grants-in-Aid for Scientific Research	407,629	343,824	399,311	422,846	407,902
Funds for Commissioned Research	1,344,071	1,890,012	1,007,060	1,076,220	1,037,842
FIRST Program ※1・NEXT Program ※2	671,668	660,578	0	0	0
Donations	40,714	38,100	16,890	14,490	36,190
Total	2,464,082	2,932,514	1,423,261	1,513,556	1,481,934

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

Annual Report 2016

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