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Annual Report 2017

Research Institute of Electrical Communication Tohoku University

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Annual report of Research Institute of Electrical Communication 2017

Contents

1. Introduction

It is the mission of RIEC to realize a new paradigm of communications that enriches people's lives. Communication is important in various ways in human society. Information communication technology (ICT) has been changing the way we deal with information drastically, overriding our biological limitations and expanding the world of communication from among people to among things as well as between people and things. RIEC is determined to work for future society with further advanced ICT, contributing to the welfare of human beings by opening up a new era of academically rooted innovation befitting a university.

The environment in which Tohoku University and RIEC operate is constantly changing. The current fiscal year marks the third 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 (IoT)," 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, we are living in a time when universities are expected to form the nucleus of innovation. In order to meet these expectations, 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.

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 third 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 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

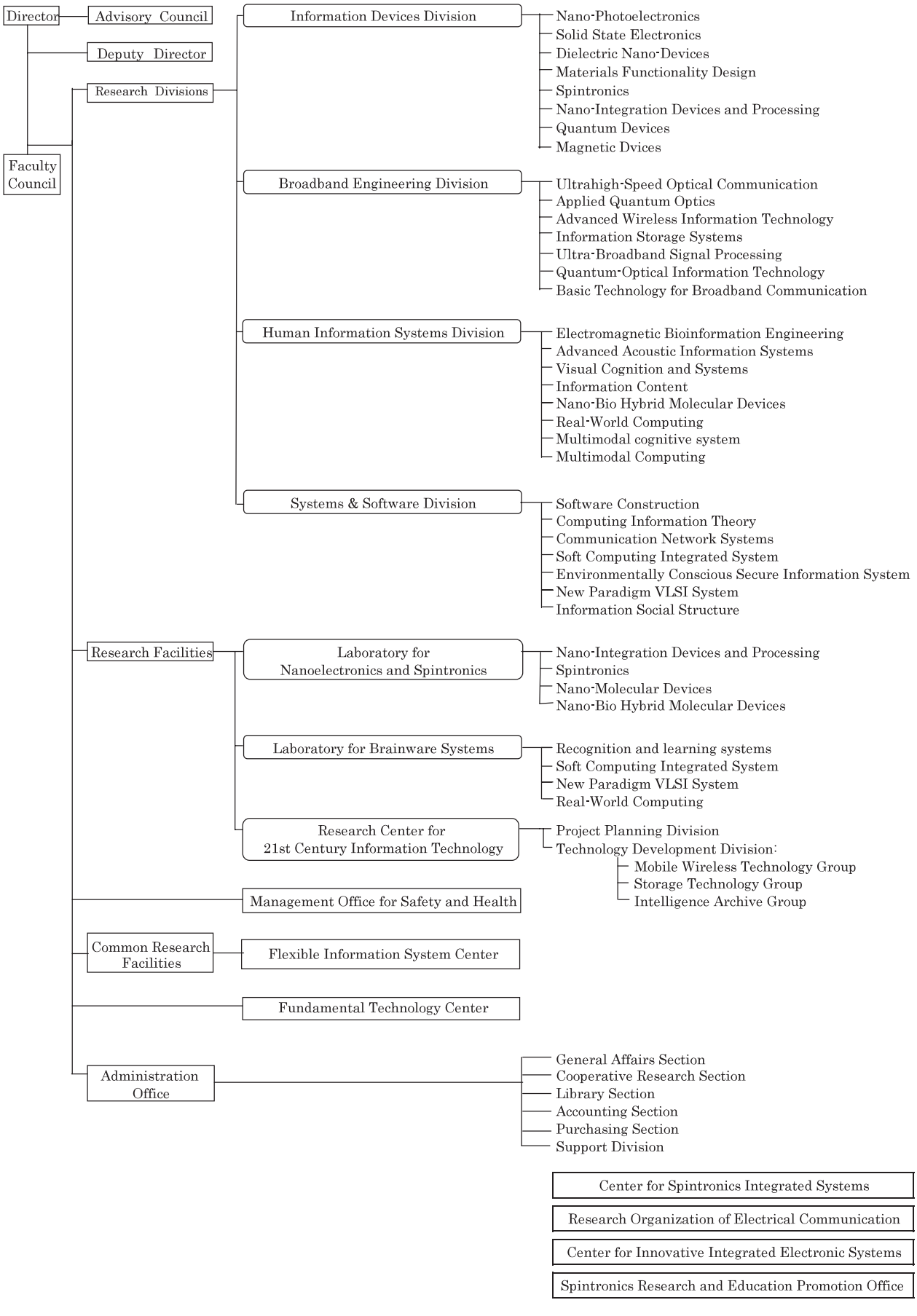
contributions, the RIEC symposia, activities of the engineering research association, and RIEC lectures. The bibliography section also includes data on the various activities we have conducted over the last five years.

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

May 24, 2018

Satoshi Shioiri
Director, Research Institute of Electrical Communication

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 8 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 and quantum electronics for next generation semiconductor devices, and nano-integration devices and processing for neural 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. Quantum Devices
8. Magnetic Devices (Visitor Section)

The research target and the summary of activities of each sub-division in 2017 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 2017 is as follows. (1) We have investigated the temporal behavior of Sb_2Te_3 after irradiation with ps pump-laser pulses using scanning tunneling microscope light emission (STM-LE) spectroscopy. The gap energy at the F point in the band diagram of Sb_2Te_3 was determined from the STM-LE spectra as a function of the delay time. We concluded that the phase transition induced by the pump pulses proceeds halfway from the crystalline to the amorphous phase. The phonon energy of the A_{2u} mode is clearly seen in the STM-LE spectra of the crystalline phase Sb_2Te_3, which is consistent with the previous Raman studies. (2) We investigated the effects of phonon vibrations of an adsorbed molecule placed in the STM gap on STM-LE; the enhancement factors for the total dipole were numerically obtained and the characteristics of the LSPLs were analyzed. The presence of a dynamic dipole in the tip–sample gap was found to create a large dynamic dipole through the generation of the LSPLs, which induces the step structure in the STM-LE spectra. (3) The nanoscale optical and electronic properties of a thermally reduced graphene oxide (GO) have been investigated using STM, PL and Raman spectroscopies. The STM observation revealed that the thickness of GO is reduced to be 0.4 nm when the thermal reduction was carried out on Au(111) covered with the C_8S-SAM. We found that the reduced GO exhibits the strong luminescence in the visible light region due to the formation of the isolated sp^2 domain.

[Staff]

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

[Profile]

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

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

[Papers]

1. S. Katano, H. Fujita, and Y. Uehara, "Investigation of local modification and luminescence of a carbon nanotube by scanning tunneling microscopy", Appl. Phys. Lett, 112, 011601-1_5 (2018).
2. Y. Uehara, J. Michimata, S. Watanabe, S. Katano, and T. Inaoka, "Determining the phonon energy of highly oriented pyrolytic graphite by scanning tunneling microscope light emission spectroscopy", J. Appl. Phys., 123, 104306-1_9 (2018).
3. J. Sakai, S. Katano, M. Kuwahara, and Y. Uehara, "Pump–probe STM Light Emission Spectroscopy for Detection of Photo-induced Semiconductor–metal Phase Transition of VO_2", J. Phys.: Condens. Matter., 29, 405001_1-7 (2017).
4. T. Inaoka, and Y. Uehara, "Classical electricity analysis of the coupling mechanisms between admolecule vibrations and localized surface plasmons in STM for vibration detectability", J. Appl. Phys., 122, 085306 (2017).
5. S. Katano, T. Wei, T. Sasajima, and Y. Uehara, "Nanoscale Observation of a Single Graphene Oxide Layer Using Scanning Tunneling Microscopy", J. Vac. Soc. Jpn., 60, 495-498 (2017).

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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

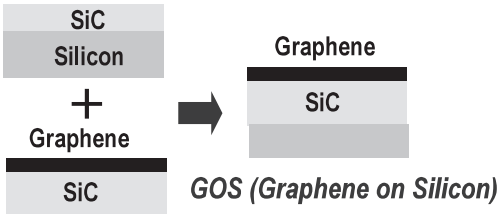
[Research Target and Activities]

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). 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 FY2017, we succeeded in obtaining drain current saturation of graphene transistors, which inhibits graphene device applications, and developing a novel method tuning the graphene/SiC interaface by using microwave. Furthermore, we developed spatiotemporal operando x-ray spectroscopy, enabling spatio-temporally examining electronic states of devices.

[Staff]

Professor : Maki Suemitsu, Dr.
Assistant Professor : Hirokazu Fukidome, Dr.
Visiting Professor : Hiroyuki Nagasawa, Dr.
Research Assistant : Fuminori Sasaki, Mr.
Research Assistant : Kwan-Soo Kim, Dr.
Research Assistant: Venugopal Gunasekaran
Technical Assistant : Kumi Namiiri
Technical Assistant : Misako Suzuki



[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). M. Ishida Research Foundation Award (2015). RIEC Award (2016).

[Papers]

[1] T. Someya, **H. Fukidome**, H. Watanabe, T. Yamamoto, M. Okada, H. Suzuki, Y. Ogawa, T. Iimori, N. Ishii, T. Kanai, K. Tashima, B. Feng, S. Yamamoto, J. Itatani, F. Komori, K. Okazaki, S. Shin, and I. Matsuda, "Suppression of Supercollision Carrier Cooling in High Mobility Graphene on SiC(000-1)", Physical Review B, Vol. 95, pp. 165303-1-165303-7 (2017).

[2] K.-S. Kim, G.-H. Park, **H. Fukidome**, S. Takashi, I. Takushi, K. Fumio, I. Matsuda, M. Suemitsu, "A table-top formation of bilayer quasi-free-standing epitaxial graphene on SiC(0001) by microwave annealing in air", Carbon, 130, pp. 792-798 (2018).

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.

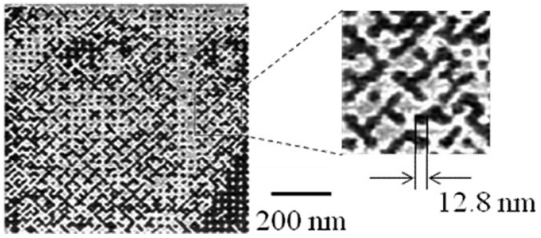


Fig.1 Digital bit data written on ferroelectric single crystal with the areal recording density of 4 Tbit/inch^2.

Major achievements of studies in 2017 are as follows: (1) Time-resolved SNDM has been developed, which allows the nanosecond time-scale analysis of electronic properties in a nanometer resolution. This method will be used for the measurement of interface state density in semiconductor materials and devices (2) We developed a SNDM-based method for the characterization of nanoscale dynamics in ferroelectric domain switching phenomena towards the realization of ferroelectric probe data storage technology (3) We clarified the mechanism of improved spatial resolution and reduced background signal in the linear permittivity imaging by dC/dz-SNDM using higher harmonic signals.

[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] Y. Hiranaga, N. Chinone, and Y. Cho: "Nanoscale linear permittivity imaging based on scanning nonlinear dielectric microscopy", Nanotechnology, Vol. 29, No.20, pp. 205709.1-9, 2018
[2] Y. Yamagishi and Y. Cho: "Nanosecond microscopy of capacitance at SiO_2/4H-SiC interfaces by time-resolved scanning nonlinear dielectric microscopy", Appl. Phys. Lett., Vol. 111, No. 16, pp. 163103-1-5, 2017
[3] Y. Hiranaga, T. Mimura, T. Shimizu, H. Funakubo, and Y. Cho: "Dynamic observation of ferroelectric domain switching using scanning nonlinear dielectric microscopy", Jpn. J. Appl. Phys., Vol.56, No. 10S, pp.10PF16-1-7, 2017

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Materials Functionality Design

Computational Design of Functional Materials for Information Devices

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 2017 are as follows:

(1) Voltage control of magnetic anisotropy (VCMA)

The Ir doping into the MgO/Fe interface enhances the VCMA effect, which is caused by the huge spin-orbit coupling of the Ir atom and the strong hybridization between the Fe 3*d* and Ir 5*d* orbitals [3].

(2) Dense metallic hydrides

New metallic Zr hydrides at high pressures are proposed by using first-principles methods. Especially in ZrH_6, superconducting transition temperature is estimated to exceed 100 K. The study also predicts the structural similarities among Mg, Sc, and Zr hydrides, suggesting the existence of diagonal relationships.

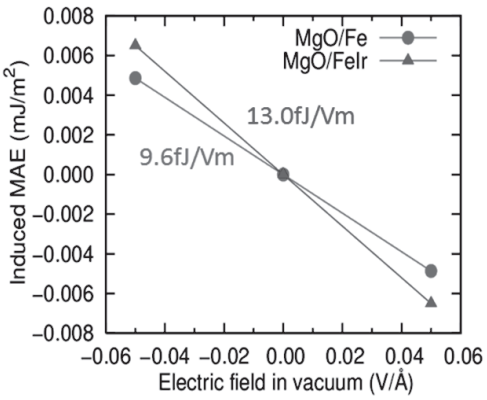


Fig. 1: The electric-field dependence of magnetic anisotropy energy (MAE) for the MgO/Fe and MgO/FeIr films [3].

[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] S. Miwa, M. Suzuki, M. Tsujikawa, K. Matsuda, T. Nozaki, K. Tanaka, T. Tsukahara, K. Nawaoka, M. Goto, Y. Kotani, T. Ohkubo, F. Bonell, E. Tamura, K. Hono, T. Nakamura, M. Shirai, S. Yuasa and Y. Suzuki, "Voltage control of platinum orbit: A contribution to interfacial magnetism," Nature Commun., Vol. 8, Article no. 15848, pp. 1-9, 2017

[2] K. Abe, "Hydrogen-rich scandium compounds at high pressures," Phys. Rev. B, Vol. 96, No. 14, Article no. 144108, pp. 1-7, 2017

[3] T. Nozaki, A. Koziol-Rachwal, M. Tsujikawa, Y. Shiota, X. Xu, T. Ohkubo, T. Tsukahara, S. Miwa, M. Suzuki, S. Tamaru, H. Kubota, A. Fukushima, K. Hono, M. Shirai, Y. Suzuki and S. Yuasa, "Highly efficient voltage control of spin and enhanced interfacial perpendicular magnetic anisotropy in iridium-doped Fe/MgO magnetic tunnel junctions," NPG Asia Mater., Vol. 9, Article no. e451, pp. 1-10, 2017

Spintronics

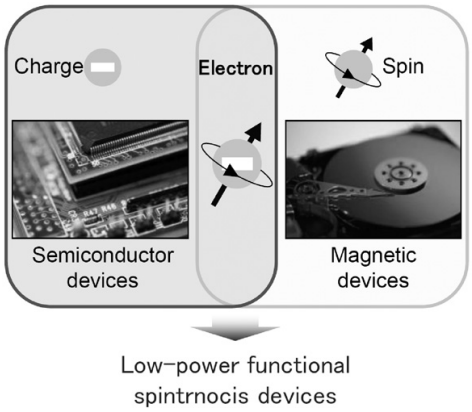
Advanced technology for spintronics-based devices

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 high spin-orbit torque switching efficiency and high thermal stability factor of Co/Pt multilayer, (2) investigation of spin-orbit interaction related phenomena in antiferromagnet-ferromagnetic system (3) achievement of single-digit-nanometer-scale high-performance magnetic tunnel junction utilizing shape 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), APS fellow (2012), and IEEE fellow, 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), the Harada Young Research Award (2015), DPS Paper Award (2016), ImPACT Symposium – Best Poster Award (2017), and Aoba Foundation Award (2017).

[Papers]

[1] B. Jinnai, C. Zhang, A. Kurenkov, M. Bersweiler, H. Sato, S. Fukami, and H.Ohno, "Spin-orbit torque induced magnetization switching in Co/Pt multilayers," Appl. Phys. Lett. **111**, 102402 (2017).
[2] S. DuttaGupta, T. Kanemura, C. Zhang, A. Kurenkov, S. Fukami, and H. Ohno, "Spin-orbit torques and Dzyaloshinskii-Moriya interaction in PtMn/[Co/Ni] heterostructures," Appl. Phys. Lett. **111**, 182412 (2017).
[3] K. Watanabe, B. Jinnai, S. Fukami, H. Sato, and H. Ohno, "Shape anisotropy revisited in single-digit nanometer magnetic tunnel junctions," Nature Communications **9**, 663 (2018).

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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) Toward the development of computation algorithms utilizing quantum parallelism, we have proposed a learning method for qubit networks. We applied it to an associative memory problem and confirmed that a modified Hebb rule works efficiently. (2) By using low-energy ECR plasma CVD without substrate heating, in addition to epitaxial growth of heavily B-doped and high carrier-mobility Si film (46 $cm^2 V^{-1} s^{-1}$ at $2.5x10^{19}$ cm^{-3}), effective suppression of reverse-bias current in a pn junction with the B-doped Si has been demonstrated.

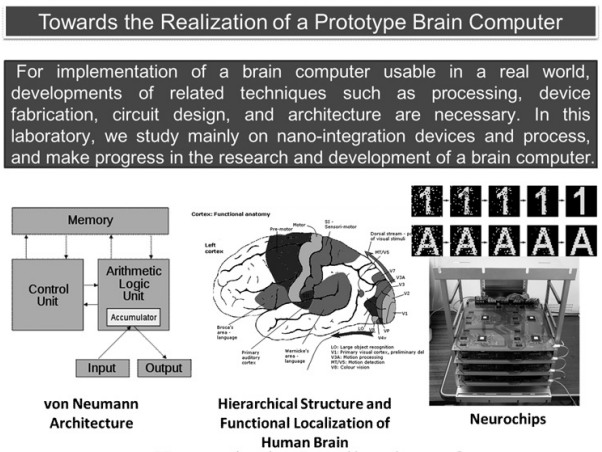
[Staff]

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

[Profile]

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

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



Towards the Realization of a Prototype Brain Computer

[Papers]

[1] Y. Osakabe, H. Akima, M. Sakuraba, M. Kinjo, S. Sato, "Quantum Associative Memory with Quantum Neural Network via Adiabatic Hamiltonian Evolution," IEICE Transactions on Information and Systems, vol.E100-D, pp.2683-2689, 2017.
[2] M. Sakuraba, K. Sugawara, T. Nosaka, H. Akima and S. Sato, "Carrier properties of B atomic-layer-doped Si films grown by ECR Ar plasma-enhanced CVD without substrate heating," Science and Technology of Advanced Materials, vol.18, pp.294-306, 2017.
[3] N. Ueno, M. Sakuraba, H. Akima and S. Sato, "Electronic Properties of Si/Si-Ge Alloy/Si(100) Heterostructures Formed by ECR Ar Plasma CVD without Substrate Heating," Materials Science in Semiconductor Processing, vol.70, pp.55-62, 2017.

Quantum Devices

Electronic properties of nanostructures and device applications

Quantum Devices: Tomohiro Otsuka, Associate Professor

[Research Target and Activities]

In solid-state nanostructures, exotic phenomena like quantum effects occur. We are exploring interesting properties of solid-state nanostructures utilizing precise and high-speed electric measurement and control techniques. We are also developing materials and devices utilizing nanostructures.

Our research activities in FY 2017 are the following.

(1) Development of high-speed electric microprobes

We improved the operation of the local electronic probes which can directly access local electronic states in nanostructures utilizing high-frequency measurement techniques.

(2) Measurement of local electronic states and their dynamics

We measured real-time change of local electronic and spin states in a hybrid system which consists of a semiconductor quantum dot and an electronic reservoir. We revealed the detail of local dynamics induced by the lower and higher order tunneling processes [2].

(3) Quantum bit experiments

We applied the local measurement techniques to quantum bit experiments. We realized precise quantum bit operations by reducing nuclear effects in the material and multiple quantum dot operations [1,3].

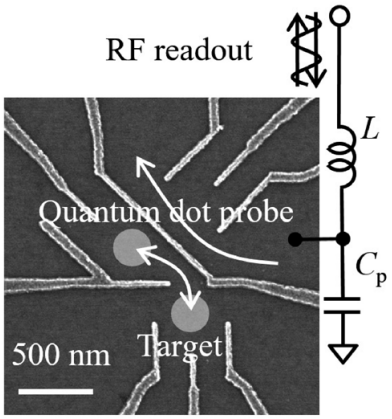


Figure: Scanning electron micrograph of a nanostructure device

[Staff]

Associate Professor: Tomohiro Otsuka, Ph. D.

[Profile]

Tomohiro Otsuka received Ph. D. degree from the University of Tokyo in 2010. After working for the University of Tokyo and RIKEN, he became an Associate Professor at Tohoku University in 2018. He received Research Encouraging Prize from School of Science, University of Tokyo (2010), NF Foundation R&D Encouragement Award (2016), Young Scientist Award of the Physical Society of Japan (2017), RIKEN Researcher Incentive Award (2017), Foundation Advanced Technology Institute Research Encouraging Award (2017), Yazaki Memorial Foundation for Science and Technology Research Encouraging Award (2018), and the Young Scientists' Prize of Science and Technology by MEXT (2018).

[Papers]

[1] T. Nakajima, M. R. Delbecq, T. Otsuka, P. Stano, S. Amaha, J. Yoneda, A. Noiri, K. Kawasaki, K. Takeda, G. Allison, A. Ludwig, A. D. Wieck, D. Loss, and S. Tarucha, "Robust Single-Shot Spin Measurement with 99.5% Fidelity in a Quantum Dot Array", Physical Review Letters 119, 017701 (2017).

[2] T. Otsuka, T. Nakajima, M. R. Delbecq, S. Amaha, J. Yoneda, K. Takeda, G. Allison, P. Stano, A. Noiri, T. Ito, D. Loss, A. Ludwig, A. D. Wieck, and S. Tarucha, "Higher-order spin and charge dynamics in a quantum dot-lead hybrid system", Scientific Reports 7, 12201 (2017).

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Broadband Engineering Division: Research Targets and Results

In order to establish future broadband communication systems and novel devices that can be flexibly applied to future ubiquitous ultra-high capacity information communications, research and development is being carried out over the wide spectrum of microwaves, millimeter/submillimeter waves, terahertz waves, and lightwaves with regard to information generation, transmission, processing, and storage technologies.

(1) Advanced Wireless Information Technology

We are actively engaged in research work on dependable wireless information technologies for next generation wireless systems, which include terrestrial / satellite communications. We cover the all technical fields from the lower to higher layers, i.e., signal processing, RF/Mixed signal device, antenna, MODEM and network technologies. We have developed a load balancing method using route estimation of mobile terminal. We have also developed RF-IC and modules like sample-hold circuit for high speed and low power wireless communication systems.

(2) Ultra-Broadband Signal Processing

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

First, 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 as well as amplified spontaneous broadband emission ranging from 1 to 7.6 THz by using our original distributed feedback dual-gate device structure. Second, for the realization of photonics-electronics convergence devices, we demonstrated the frequency down-conversion of 1.5-μm optical data signal with 12-GHz ASK/BPSK modulation to 22.5-GHz millimeter-wave IF data signal using an InGaAs-channel high-electron-mobility transistor.

(3) Ultrahigh-Speed Optical Communication

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

This year, we successfully demonstrated a single-channel 7.68 Tbit/s, 64 QAM coherent Nyquist pulse transmission with a spectral efficiency (SE) of 9.7 bit/s/Hz. In addition, we realized a 4096 QAM transmission for the first time with an SE as high as 15.8 bit/s/Hz. We also found that GAWBS (Guided Acoustic Wave Brillouin Scattering) noise adversely affects transmitted data in digital coherent transmission with high multiplicity. Novel digital and analog compensation schemes were proposed, which resulted in the suppression of the error floor that was otherwise difficult to remove.

(4) Applied Quantum Optics

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

A study on ultra-high-speed semiconductor lasers is being continued. It was confirmed numerically that the hybrid modulation laser we proposed will have a 3-dB bandwidth close to 100 GHz when the cavity loss modulation region acts as an external cavity. A study on compact and narrow linewidth semiconductor lasers is also progressing by applying the optical negative feedback method. It was confirmed that a compact semiconductor laser source with a spectral linewidth of 160 kHz can be realized by integrating a Si ring filter with DFB-LD hybridly. Furthermore, the study of TDM Nyquist pulse generation from an optical NRZ signal is being carried out by using a Mach-Zehnder modulator (MZM). It was confirmed that a 10 Gbps optical TDM Nyquist pulse can be generated by using a simple scheme with an EADFB-LD and the MZM.

(5) Information Storage Systems

Research on next-generation perpendicular magnetic recording is being carried out to meet the strong demand for high density, low cost storage due to the rapid growth of the Internet and web services.

We have been investigating novel, three dimensional, energy-assisted recording technologies that enable selective recording on media with multiple, discrete recording layers. Methods to reduce interactions between the recording layers have also been proposed. Composite media designs to improve the recording performance of heat-assisted magnetic recording systems have been developed. Such media structures can also lead to higher data rates during recording. The simultaneous readback of two tracks with single or multiple readers was investigated in order to increase the data transfer rate during reading.

(6) Quantum·Optical Information Technology

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

In 2017, we have achieved (1) quantum interference of unpolarized single-photons 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 and cold atoms to a nanofiber surface and the first measurement of the chiral polarization response.

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 7.68 Tbit/s, 64 QAM coherent Nyquist pulse transmission with a spectral efficiency (SE) of 9.7 bit/s/Hz, and a single-channel 10.2 Tbit/s transmission over 300 km using non-coherent Nyquist pulses with an SE of 2.5 bit/s/Hz. In addition, we realized a 4096 QAM transmission for the first time with an SE as high as 15.8 bit/s/Hz (Fig. 1). We also found that GAWBS (Guided Acoustic Wave Brillouin Scattering) noise adversely affects transmitted data in digital coherent transmission with high multiplicity. Novel digital and analog compensation schemes were proposed, which resulted in the suppression of error floor that was otherwise difficult to remove.

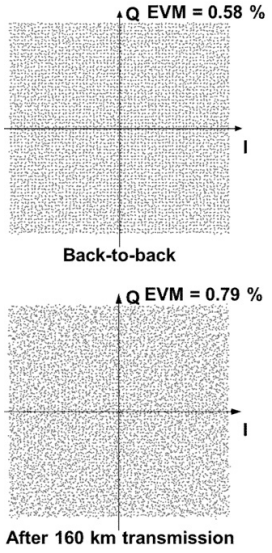

Fig. 1. Constellations of 72 Gbit/s, 4096 QAM signal before and after 160 km transmission.

[Staff]

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

[Profile]

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

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]

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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 numerically that the hybrid modulation laser we proposed will have a 3-dB bandwidth close to 100 GHz when the cavity loss modulation region is act as external cavity which arises the photon-photon resonance effect.

The study on compact and narrow linewidth semiconductor laser sources is also being proceeded by applying the optical negative feedback method we proposed. It was confirmed that the compact semiconductor laser source with spectral linewidth of 160 kHz can be realized by integrating a Si ring filter with DFB-LD hybridly.

Furthermore, the study on a TDM Nyquist pulse generation from optical NRZ signal is being carried out by using a Mach-Zehnder modulator (MZM) with harmonic superposition of RF signals to the modulator. It was confirmed that 10 Gbps optical TDM Nyquist pulse can be generated by using a simple scheme with an EADFB-LD and the MZM.

Schematic structure of a hybrid modulation LD (left), compact narrow linewidth semiconductor laser (center), and interference waveform for TDM Nyquist pulse (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] N. Yokota, R. Takeuchi, H. Yasaka, and K. Ikeda, "Lasing Polarization Characteristics in 1.55-mm Spin-Injected VCSELs," IEEE Photonics Technology Letters, vol. 29, No. 9, pp. 711-714, 2017. / DOI 10.1109/LPT.2017.2681129

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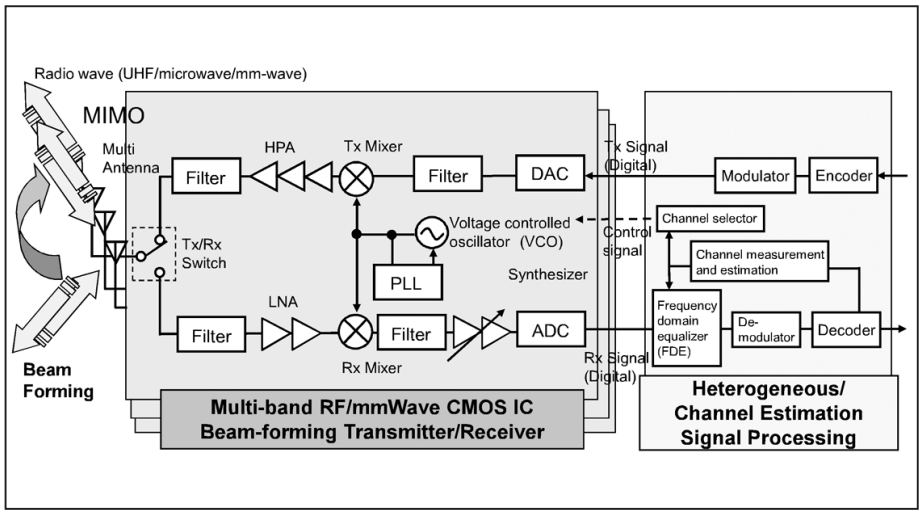
Advanced Wireless Information Technology

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.



We have developed load balancing method using route estimation of mobile terminal. 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] T. Maehata, *et al.*, "Cancellation for asymmetrical waveform in 1-bit bandpass delta-sigma modulators," IEICE Trans. Communications vol.E100-B, no.6, pp.1017-1022, June, 2017.
[2] T. Maehata, *et al.*, "1-bit band-pass delta-sigma modulator with parallel IIR form for concurrent multiband digital transmitter," IEICE Trans. Communications Vol.E100-B, No.7, pp.1152-1159, Jul. 2017.
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Information Storage Systems

High Density and High Speed Energy-Assisted Magnetic Recording

Information Storage Systems: Hiroaki Muraoka, Professor
Information Storage Devices: Simon Greaves, Associate Professor

[Research Target and Activities]

We have been working on technologies to increase the speed and density of magnetic recording devices. During this year two types of energy-assisted magnetic recording were investigated: heat-assisted magnetic recording (HAMR) and microwave-assisted magnetic recording (MAMR).

In a MAMR system it is possible to record information on a medium consisting of multiple, discrete storage layers. This is achieved by using storage layers with different ferromagnetic resonance frequencies. During recording a spin torque oscillator located next to the write head generates a high frequency magnetic field at the resonance frequency of one of the storage layers, enabling selective recording of that layer only. The work in [1] describes the results of simulations of a three layer storage medium.

The work in [2] considers how to optimise the shape of the head field pulse in a MAMR system in order to maximise the switching probability and signal to noise ratio. Different optimal pulse shapes were found for different media structures.

An alternative future recording technology, HAMR, was investigated in [3]. In order to minimise errors and data loss the switching probability of media grains should be as close as possible to 1. The use of composite recording media, consisting of magnetically hard and soft layers exchange-coupled together, was found to increase the switching probability of media grains when compared with single phase media.

Composite media structures can also be used to reduce the time taken for the grain magnetisation to switch from one direction to another, allowing increased data rates during writing. In [4] the switching times of single phase and graded anisotropy grains were compared, with the switching time of the latter being 2/3 of the former.

[Staff]

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

[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 theory, mainly for perpendicular magnetic recording. He received his Ph.D. degree in 1981. He is an IEEE Fellow.

Simon Greaves has been at Tohoku University since 2003. He developed micromagnetic simulation software to model magnetic recording and to investigate the potential of future storage devices. He received his Ph.D. in 1993 from Salford University, U.K.

[Papers]

[1] S. Greaves, Y. Kanai and H. Muraoka, IEEE Transactions on Magnetics 53(2), 3000510-1-10, (2017).
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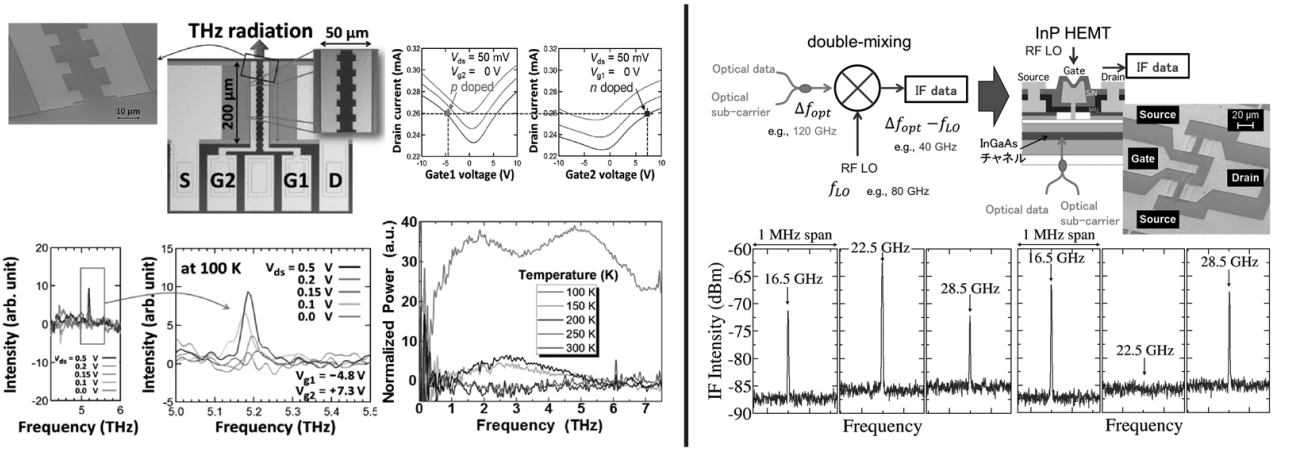
Ultra-broadband Signal Processing

Novel Millimeter-wave and Terahertz Integrated Electron Devices and Systems

Ultra-Broadband Devices and Systems: Taiichi OTSUJI, Professor
Ultra-Broadband Device Physics: Akira SATOU, 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 (left) and broadband amplified spontaneous emission ranging from 1 to 7.6 THz (right), right: the concept of the photonic double-mixing functionality using an InP HEMT and its SEM image (top), measured down-converted 12-GHz ASK/BPSK modulated signals (bottom left/bottom right) from 1.5-μm optical signals to 22.5-GHz millimeter-wave IF data signal using an InP HEMT.

We are developing novel, integrated electron devices and circuit systems operating in the terahertz (THz) region. Towards 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 at 5.2 THz and broadband amplified spontaneous emission raging from 1 to 7.6 THz at 100K. Also, we are researching carrier frequency down-converters from optical to wireless data signals, which is one of key technologies in future photonics-electronics convergence networks. This fiscal year, we have demonstrated the frequency down-conversion of 1.5-μm optical data signal with 12-GHz ASK/BPSK modulation to 22.5-GHz millimeter-wave IF data signal using an InP-based high-electron-mobility transistor (InP HEMT).

[Staff]

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

[Profile]

Taiichi OTSUJI: received the Dr. Eng. deg. from Tokyo Tech., Japan, in 1994. After working for NTT Labs., Japan, since 1984, he joined Kyutech in 1999, as an Assoc. Prof., being a prof. from 2002. Since 2005, he has been a Prof. at RIEC, Tohoku Univ., Japan. Recipient of the Outstanding Paper Award of the 1997 IEEE GaAs IC Symposium. Distinguished Lecturer, Electron Device Society, IEEE, since 2013. Member of IEEE (Fellow), OSA (Senior), MRS, SPIE, IEICE, and JSAP.
Akira SATOU: received Dr. Comp. Sci. from Univ. of Aizu, Japan, in 2008. He was an Assistant Lecturer, ISTC, Univ. of Aizu, in 2008 and CAIST, Univ. of Aizu, in 2009. He joined RIEC, Tohoku Univ., Japan, in 2010 as an Assistant Professor and was promoted to an Associate Professor in 2017. He is a member of IEEE (Senior), APS, JSAP, and IEICE.

[Papers]

[1] D. Yadav, G. Tamamushi, T. Watanabe, J. Mitsushio, Y. Tobah, K. Sugawara, A.A. Dubinov, M. Ryzhii, V. Ryzhii, and T. Otsuji, "Terahertz light-emitting graphene-channel transistor toward single-mode lasing," Nanophoton., vol. 7, iss. 4, pp. 741-752, 2018.
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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 2017, we have achieved (1) quantum interference of unpolarized single-photons 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 and cold atoms to a nanofiber surface and the first measurement of the chiral polarization response.

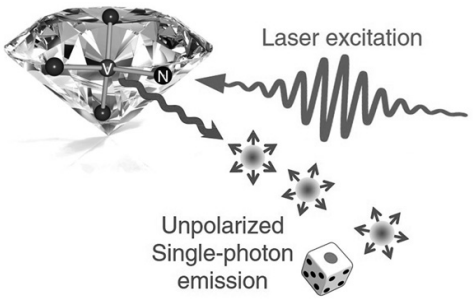

Fig. Schematic picture of unpolarized single-photon generation using a compound defect, a nitrogen vacancy center (NV center), in a diamond.

[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] 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, six 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-Bio Hybrid Molecular Devices.

The goals and achievements in the fiscal year 2017 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. The obtained proto-type system was demonstrated on JASIS2018 exhibition. On the work of high frequency magnetic field measuring system, we have succeeded in imaging the distribution of up to 6GHz magnetic field generated from electronic circuits by our proposed system. This system was also demonstrated on exhibition. The study about nanostructured magnetic materials using magnetic nanoparticles was carried out for the creation of novel functional materials such as extraordinary strong magnets.

(2) Advanced Acoustic Information Systems

(Aim) To propose high-definition communication systems that attain rich and natural sense of presence. To this end, we are developing acoustic information processing technologies based on well-grounded knowledge of the human auditory system and the multimodal perception processes related to hearing.

(Achievements) We have been developing advanced acoustic systems, such as 3D virtual auditory displays, sound acquisition and presentation systems with over one hundred

channels, and real-time systems for the binaural rendering of 252-channel recordings. These systems make use of physical acoustic modeling, such as high-order Ambisonics, and combine them with dense datasets of spatial transfer functions, such as the head-related transfer function (HRTF). These results are expected to be of great significance in the development of super-definition audio-visual communications in the near future.

Moreover, our efforts have deepened our understanding of spatiotemporal perception of audio-vestibular information. In addition, we carried out studies into the effects that physical factors have on our perception of presence and verisimilitude in multimodal contents including auditory, visual and vestibular information. These studies are critical for the development of novel multimodal sensory information processing and communication systems.

(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 using an EEG technique and found that there are multiple stages of the attention mechanisms: one is for facilitating the process around the attention focus and the other is for selecting items at the attentional focus. Secondly, we proposed a numerical model of color appearance. The human visual system adapts to new illuminant environment and the achromatic points (white, gray, black) varies with it in a non-linear fashion. A simple approximation was implemented in a numerical model to simulate this achromatic point shifts under illuminant change. This model succeeded in visualizing the color appearance for #theDress image, which became famous for huge individual differences caused by the estimation of illuminant color and intensity.

(4) Information Content

(Aims) As the Internet of Things (IoT) expands, everything around us coming online and joining integrated networks. Even everyday items like furniture are going digital. We view all artifacts, physical and digital, as content. Honoring the unique perspectives of people, systems, and the environments they inhabit, we study the interactions between types of content, with the ultimate goal of formulating cohesive, holistic, and intuitive approaches that promote efficiency, ease of use, and effective communication, we focus on content design to enhance living.

(Achievements)

This year we proposed an in-the wild gesture data collection system based on rhythm game. We also proposed a transformable digital table using moving multiple small tables

that physically adapts user's interactions over the table. Moreover, we built a VR simulator with a tree-shape interaction history visualization that helps user's training activities.

(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 2017 are summarized as follows: (1) we have demonstrated the applicability of *Tegotae*-based control scheme, which we proposed previously, to various types of locomotion such as hexapods, earthworms, and snakes via simulations and real-world experiments with robots; (2) we have succeeded in developing a brittle-star like robot that can immediately adapt to physical damage. This result has been advertised in the press; (3) we have succeeded in formulating body-limb coordination mechanisms of quadruped locomotion, and applied it to other animals such as centipedes and sea roaches.

(6) 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 reported on optimized nano- and micro-structures for mechanically stable bilayer lipid membranes (BLMs) using Si microfabrication techniques. We also succeeded in reconstitution of cell-free synthesized wild type hERG channels into the BLMs and recording their activity at the single-channel level. By growing primary neurons on a microfabricated coverslip, we investigated structure-function relationships in neuronal networks. We also used computational models to provide graph theoretical interpretations on experimental data. Another achievement is analysis of the charge transfer mechanism in organic solar cells. We also proposed a new structure of high-performance and cost-effective perovskite solar cells.

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 measurement system, fabrication of high sensitive strain sensors on Si wafer and the design of detection circuits with low noise were carried out. On the work of high frequency magnetic field measuring system, imaging sensitivity of high frequency magnetic field was promoted by applying new technologies. In addition, wireless magnetic motion capture system with four-excitation-coils was studied to improve its detection accuracy. The study about nanostructured magnetic materials using magnetic nanoparticles was carried out for the creation of novel functional materials.

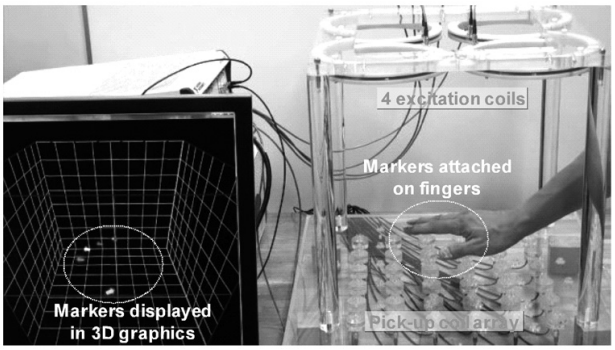

Fig. 1 Wireless motion capture system using four-excitation-coils [1].

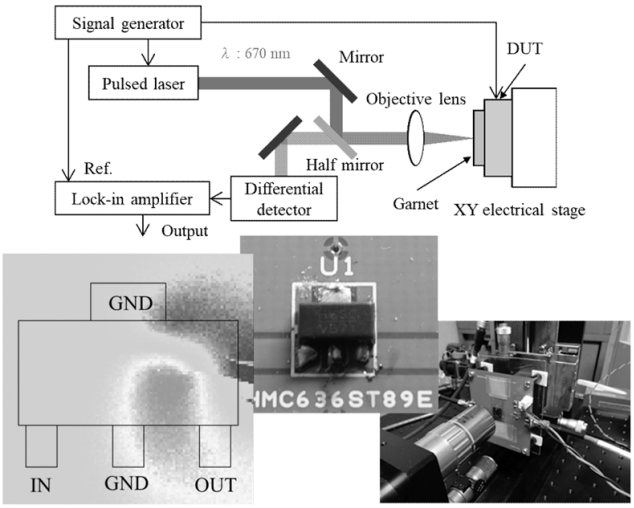

Fig. 2 High frequency magnetic field measuring system using magneto-optical crystal probe

[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] Yutaro Osaki, Shuichiro Hashi, Shin Yabukami, Hiroyasu Kanetaka, Kazushi Ishiyama, "Wireless magnetic position-detection system with four excitation coils," IEEE Sensors Journal, Vol. 17, No. 14, pp. 4412-4419 (2017).
[2] Hiroaki Kikuchi, Chihiro Sumida, Tomoo Nakai, Shuihiro Hashi, Kazushi Ishiyama, "Effects of dc bias current on behaviors and sensitivity of thin-film magnetoimpedance element," IEEE Transactions on Magnetics, Vol. 53, 4003704 (2017).
[3] Yoshiaki Hayashi, Tomoyuki Ogawa, and Kazushi Ishiyama, "Preparation and characterization of SiO_2-coated submicron-sized $L1_0$ Fe-Pt particles," AIP Advances, Vol. 8, 056416 (2018).
[4] Jingyan Ma, Sho Muroga, Yasushi Endo, Shuichiro Hashi, Masayuki Naoe, Hiroo Yokoyama, Yoshiaki Hayashi, Kazushi Ishiyama, "Noise suppression and crosstalk analysis of on-chip magnetic film-type noise suppressor," AIP Advances, Vol. 8, 056613 (2018).

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 FY2017, we focused our efforts to the development of systems to acquire 3D sound-space information, store or transmit it and accurately reproduce the recorded sound space in a remote location. Apart from recording using spherical microphone arrays, from a psychoacoustical point of view, we investigated the effects of vibration in high-level perception.

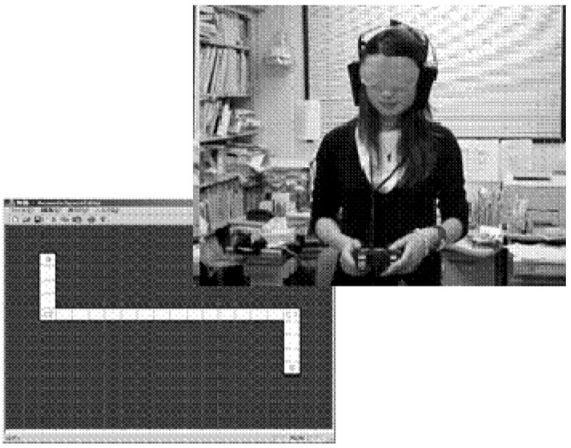

Fig. 1 Application for the training of spatial cognition using a high-definition virtual auditory display

[Staff]

Professor: Dr. Yôiti Suzuki
Associate professor: Dr. Shuichi Sakamoto
Assistant professors: Dr. Zheng Lie Cui, Dr. Jorge Trevino
Specially appointed assistant professor: Dr. Cesar Daniel Salvador
Technical Staff: Fumitaka Saito
Secretary: Miki Onodera

[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 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. Since 2016 he is serving as a board member of the Acoustical Society of Japan.

[Papers]

[1] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Enhancement of spatial sound recordings by adding virtual microphones to spherical microphone arrays," J. Inf. Hiding and Multimedia Sig. Process., 8(6), 1392–1404 (2017).
[2] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Boundary matching filters for spherical microphone and loudspeaker arrays," IEEE/ACM Trans. Audio, Speech, Lang. Process., 26(3), 461–474 (2018).
[3] Z. Cui, S. Sakamoto J. Gyoba and Y. Suzuki, "Influence of visual depth and vibration on the high-level perception of reality in 3D contents," J. Inf. Hiding and Multimedia Sig. Process., 8 (6), 1382-1391 (2017).

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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-huei 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 proposed a numerical model of color appearance under illuminant color change. The color is perceived by comparison with "achromatic points" that appear colorless under an illuminant. Our model used a simple formula to approximate the achromatic points under various illuminants. Our model successfully simulate color appearance of a famous image "#theDress", which is known to evoke different color percept among individuals. It revealed that individual differences were due to differences in "assumed" color and intensity of light falling on "the dress" in the picture.

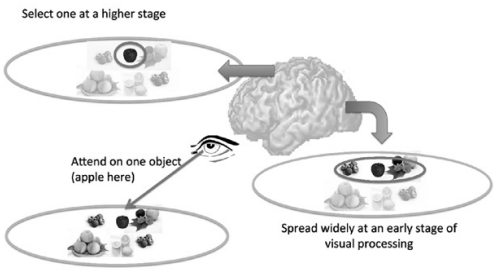

Figure. Attention spreads at an early stage of visual processing but selects local information at a later stage.

[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. He then started to work at Tokyo Institute of Technology as an Assistant Professor until October, 1999. He worked as an Assistant Professor at the Graduate School of Engineering, the University of Tokyo until March, 2001. He worked as a Researcher in Communication Science Laboratories of NTT Corporation, and as a Visiting Associate Professor at Tokyo Institute of Technology Graduate School before joining the Research Institute of Electrical Communication, Tohoku University as an Associate Professor in January, 2006. He has been investigating the mechanisms of color vision using psychophysics and functional brain imaging techniques (EEG/MEG, fMRI). Chia-huei TSENG Dr. Tseng 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.

[Papers]

1. Shioiri S. et al. (2017) Dynamic change of spatial attention measured by event related steady state visual evoked potential. *European Conference on Visual Perception 2017*, Berlin, Germany, August 25-30, 2017.
2. Kuriki I (2018). A novel method of color-appearance simulation using achromatic point locus with lightness dependence. *i-Perception*, 9(2), 1-16.

Information Content

Technologies for Interactive Content

Interactive Content Design Yoshifumi KITAMURA, Professor

[Research Target and Activities]

As the Internet of Things (IoT) expands, everything around us coming online and joining integrated networks. Even everyday items like furniture are going digital. We view all artifacts, physical and digital, as content. Honoring the unique perspectives of people, systems, and the environments they inhabit, we study the interactions between types of content, with the ultimate goal of formulating cohesive, holistic, and intuitive approaches that promote efficiency, ease of use, and effective communication, we focus on content design to enhance living.

This year we proposed an in-the wild gesture data collection system based on rhythm game [1]. We also proposed a transformable digital table using moving multiple small tables that physically adapts user's interactions over the table [2]. Moreover, we built a VR simulator with a tree-shape interaction history visualization that helps user's training activities [3].

Gesture collection system (left), Transformable displays (middle and right)

[Staff]

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

[Profile]

Since 2010, Yoshifumi Kitamura has been Professor in the Research Institute of Electrical Communication, Tohoku University. His research interests include interactive content design, human computer interactions, 3D user interfaces, and related fields. Prior to arriving at Tohoku, he was an Associate Professor at Graduate School of Engineering, and Graduate School of Information Science and Technology, Osaka University. While working at ATR Communication Systems Research Laboratories, he focused on sophisticated user interfaces in virtual environments. His first formal appointment was in the Information Systems Research Center Canon Inc., where he was involved in research on artificial intelligence, image processing, computer vision, and 3D data processing. His formal education was obtained at Osaka University, B.Sc (1985); M.Sc. (1987); and Ph.D. (1996).

[Papers]

[1] Kiyoshi Oka, Weiquan Lu, Kasim Ozacar, Kazuki Takashima and Yoshifumi Kitamura, Exploring in-the-Wild Game-Based Gesture Data Collection, INTERACT 2017, Part II, 97-106, September 2017.

[2] Yoshiki Kudo, Kazuki Takashima and Yoshifumi Kitamura, Adaptive Workspace using MovemenTable, In Proceedings of the 2017 ACM International Conference on Interactive Surfaces and Spaces (ISS '17), 401-404, October 2017.

[3] Ahmed E Mostafa, Won Hyung Ryu, Kazuki Takashima, Sonny Chan, Mario Costa Sousa and Ehud Sharlin, ReflectiveSpineVR: An immersive spine surgery simulation with interaction history capabilities, In Proceedings of Conference on Spatial User Interface, 20-29, October 2017.

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Nano-Bio Hybrid Molecular Devices

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

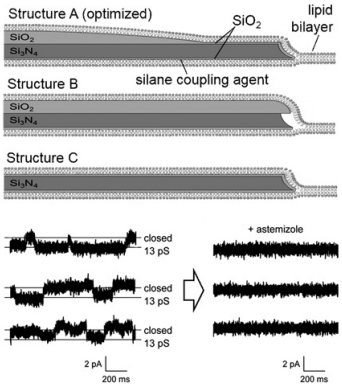
Nano-Bio Hybrid Molecular Devices: Ayumi Hirano-Iwata, Professor

[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. Reconstitution of cell-free synthesized ion channels in microfabricated Si chips

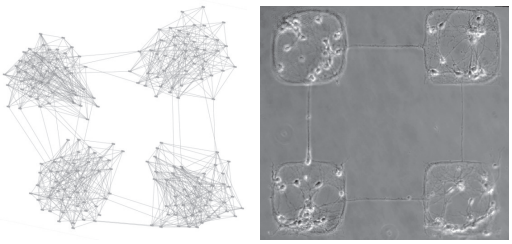
We reported on optimized nano- and micro-structures for mechanically stable bilayer lipid membranes (BLMs) using Si microfabrication techniques. We also succeeded in reconstitution of cell-free synthesized wild type hERG channels into the BLMs and recording their activity at the single-channel level. [Sci. Rep., 7, 17736 (2017).]



Reconstitution of cell-free synthesized hERG channels.

2. Reconstruction of artificial neuronal networks

By growing primary neurons on a microfabricated coverslip, we investigate structure-function relationships in neuronal networks. We also use computational models to provide graph theoretical interpretations on experimental data. Our recent work identified the influence of intra-modular connectivity on global synchronizability in modular networks. [Front. Comput. Neurosci. 12, 17 (2018).]



Micropatterned neuronal networks.

3. Charge transfer in organic solar cells and novel structure for perovskite solar cells

The charge transfer mechanism in organic solar cells has been studied by a simple displacement current technique. [Org. Electron. 51, 269-276 (2017).] To improve the performance and reduce the cost of perovskite solar cells, we proposed a new structure and verified the applicability of the new structure using numerical simulation technique. [ACS Appl. Energy Mater. 1, 970–975 (2018).]

[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.

[Papers]

[1] D. Tadaki, D. Yamaura, S. Araki, M. Yoshida, K. Arata, T. Ohori, K. Ishibashi, M. Kato, T. Ma, R. Miyata, Y. Tozawa, H. Yamamoto, M. Niwano, A. Hirano-Iwata, "Mechanically stable solvent-free lipid bilayers in nano- and micro-tapered apertures for reconstruction of cell-free synthesized hERG channels", Sci. Rep. 7, 17736 (2017).

[2] Hideaki Yamamoto, Shigeru Kubota, Fabio A. Shimizu, Ayumi Hirano-Iwata, Michio Niwano, "Effective subnetwork topology for synchronizing interconnected networks of coupled phase oscillators", Front. Comput. Neurosci. 12, 17 (2018).

[3] T. Ma, Q. Song, D. Tadaki, M. Niwano, A. Hirano-Iwata, "Unveil the full potential of integrated-back-contact perovskite solar cells using numerical simulation", ACS Appl. Energy Mater. 1, 970–975 (2018).

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.

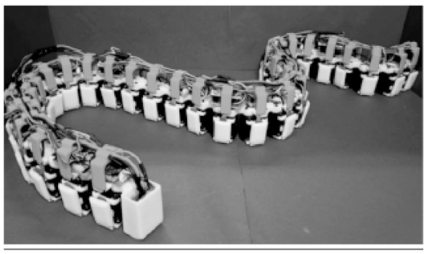


Fig.1: Snake-like robot that exhibits versatile locomotion patterns

Fig.2: Brittle star-like robot that can adapt to unexpected physical damage

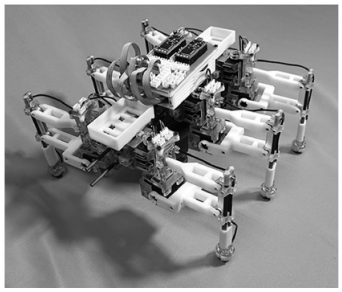


Fig.3: Hexapod robot that exhibits adaptive interlimb coordination.

[Staff]

Professor: Akio ISHIGURO, Dr.
Associate Professor: Takeshi KANO, Dr.
Postdoctoral Researcher: Akira FUKUHARA, 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. Yoshikawa and A. Ishiguro, "Tegotae-based decentralised control scheme for autonomous gait transition of snake-like robots", *Bioinspiration & Biomimetics*, 12:046009, 2017
[2] T. Kano, E. Sato, T. Ono, H. Aonuma, Y. Matsuzaka, and A. Ishiguro, "A Brittle Star-like Robot Capable of Immediately Adapting to Unexpected Physical Damage", Royal Society Open Science, 4:171200, 2017
[3] D. Owaki, M. Goda, S. Miyazawa and A. Ishiguro, "A Minimal Model Describing Hexapedal Interlimb Coordination: the Tegotae-based Approach", *Frontiers in Neurorobotics*, 11:29, 2017

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Research Targets and Activities of Systems & Software Division

The goal of System & Software Division is to realize ideal ubiquitous environment where everyone can freely communicate in real-time with anyone, anywhere, and at any time through any kind of information. Our division has the following seven research fields related to such high-level ubiquitous systems, software and contents 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. 2017 to Mar. 2018 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 2017 academic year include the following. (1) We have developed a type theory and compilation method for introducing dynamic typechecking feature in a polymorphic language. (2) We have extended our fully concurrent GC algorithm so that it works with light-weight OS threads. (3) We have integrated some of these results in the SML# compiler, and have released the SML# version 3.4.0 compiler.

(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 improved an automated ground confluence prover AGCP for term rewriting systems, by developing several methods that add wider flexibility to the rewriting induction approach. (ii) We have shown the parallel closure theorem on confluence of left-linear nominal rewriting systems.

(3) Communication Network Systems

We promoted the following research on cooperative distributed knowledge processing supporting various human activities and its application. In the research on intelligent network, we proposed a network system operation method based on fluctuation observation, a network management method based on human-agent collectives concept, and so on, and confirmed the effect through experiment using testbed system. In the study on application of active information resources, we confirmed its effect by experimentation of recall support function for individual knowledge base. In addition, in the research of agent based IoT (AIoT),

we continue to evaluate and improve the construction method of AIoT device based on agentification of IoT devices. Moreover, we propose a evacuation guidance method at disaster using AIoT drones, and evaluation and improvement were carried out by field experiment using an experiment system.

(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 lowest latency tamper-resistant Advanced Encryption Standard (AES) cryptographic processing circuit, and also developed a new formal method for verifying both functionality and security property of tamper-resistant cryptographic hardware. We also have developed the world's lowest latency PRINCE cipher hardware. Moreover, we have developed an efficient method for improving stability and uniformity of hardware-oriented physically unclonable functions used for individual identification 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. (i) We proposed a chaotic reservoir network composed of chaotic neurons, which is applicable to the reference-self system in the brain-body whole organism computing paradigm. We confirmed feasibility of the proposed chaotic reservoir network through chaotic time-series predictions. (ii) For a dynamics/algorithm sub-conscious/conscious hybrid computer system, we designed and fabricated two switched-current chaotic neural network integrated circuit chips with TSMC 65 nm CMOS and ROHM 180 nm CMOS processes. (iii) We used ordered entropy to evaluate the dynamics of a reservoir network through a chaotic time-series prediction.

(6) New Paradigm VLSI System

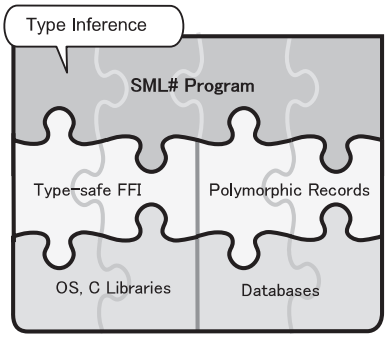
Our research activity is to solve the several limitations such as power dissipation, performance and reliability due to the present binary-CMOS-based VLSI computing. The key approach to breaking through such limitations is primarily the following two ways: the logic-in-memory architecture based on nonvolatile logic, and the brainware LSI (BLSI) computing, which would open up a novel VLSI chip paradigm, called a "new-paradigm VLSI system." In this year, we have successfully achieved (1) to design and evaluate MTJ (Magnetic Tunnel Junction)-based nonvolatile FPGA (Field-Programmable Gate Array) with a "data-shift" function, where only one-bit data stored into an LUT (Lookup Table) circuit is updated in this operation, (2) to design an interface circuit controlling data transmission between CPU and nonvolatile memory in MTJ-based nonvolatile microcontroller LSI, (3) and to design a small-area and low-power deep-learning LSI based on stochastic computing. The above research results have reported 9 academic journal papers such as IEEE Trans. VLSI Systems, 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 2017 academic year include the following: (1) we have integrated a system-provided lightweight thread library in SML#, which allows the SML# programmer to deal with a millions of lightweight threads running concurrently on multicore processors; (2) we have developed a compile technique for dynamic type check in a statically-typed language based on the idea of type-directed compilation; and (3) we have developed a typed template engine as an application of partially dynamic records. Some of these results have been implemented in the SML# compiler and released as SML# version 3.4.0.

[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] Atsushi Ohori, Kenjiro Taura, Katsuhiro Ueno: Making SML# a general-purpose high-performance language, ACM SIGPLAN Workshop on ML, 2017.
[2] Mifuyu Osaka, Katsuhiro Ueno, Atsushi Ohori: Typed template engine based on partially dynamic records (Japanese), Computer Software, to appear.

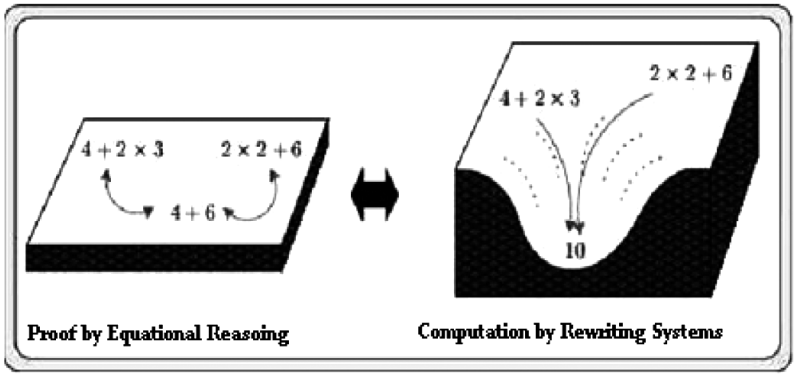
Computing Information Theory

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] Kentaro Kikuchi, Takahito Aoto and Yoshihito Toyama, Parallel Closure Theorem for Left-Linear Nominal Rewriting Systems, Proceedings of the 11th International Symposium on Frontiers of Combining Systems (FroCoS 2017), Lecture Notes in Computer Science, Vol.10483, pp.115-131, 2017.

[2] Kentaro Kikuchi, Confluence by Strong Commutation with Disjoint Parallel Reduction, Proceedings of the 4th International Workshop on Rewriting Techniques for Program Transformations and Evaluation (WPTE 2017), pp.9:1-9:10, 2017.

[3] Takahito Aoto, Yoshihito Toyama and Yuta Kimura, Improving rewriting induction approach for proving ground confluence, Proceedings of the 2nd International Conference on Formal Structures for Computation and Deduction (FSCD 2017), Leibniz International Proceedings in Informatics, Vol.84, pp.7:1-7:18, 2017.

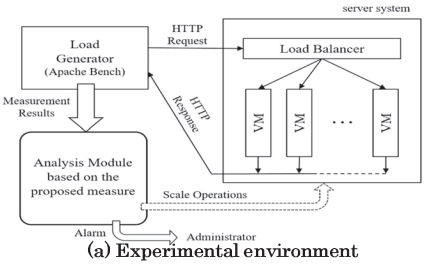
Communication Network Systems

Support for Cooperation and Communication between Human and Systems

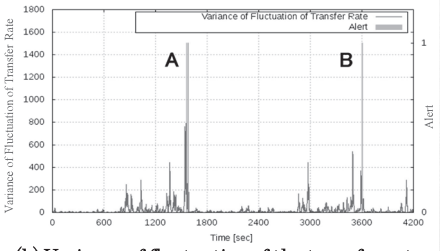
Intelligent Communication: Tetsuo Kinoshita, Professor
Intelligent Network: Gen Kitagata, Associate Professor

[Research Target and Activities]

In this year, the following studies had been done. (a) Network Management System: Management and analysis methods of the macroscopic behavior of server systems has been proposed and its effectiveness was also confirmed. (b) Educational support: Evaluation support mechanism of wooden works for practice learning management system of technology education has been developed and evaluated in an actual education site. (c) Human-Agent Collectives: A model of asynchrony in a continuous double auction market has been proposed and the influence of intermittent behavior between agents was showed.

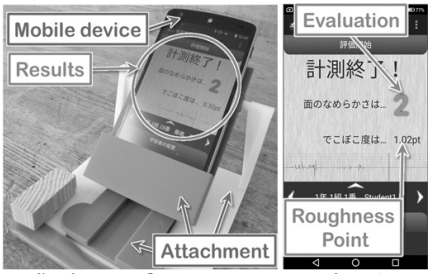


(a) Experimental environment



(b) Variance of fluctuation of the transfer rate and alert

Autonomous performance management method of network systems



Surface roughness measurement function
Evaluation support mechanism

[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] K. Sasai, Y.-P. Gunji, T. Kinoshita, "Intermittent Behavior Induced by Asynchronous Interactions in a Continuous Double Auction Model," Advances in Complex Systems, Vol.20, No.02n03, pp.1750005 (21 pages), July 2017.
[2] Y. Tanimura, K. Sasai, G. Kitagata, T. Kinoshita, "Analysis of the Macroscopic Behavior of Server Systems in the Internet Environment," Applied Sciences, Vol.7, No.11, pp.1145, Nov. 2017.
[3] R. Fukutani, S. Itagaki, H. Takahashi, A. Ando, T. Kinoshita, "Development and Evaluation of a Workpiece Evaluation Support Mechanism for Students," Information Engineering Express International Institute of Applied Informatics, Vol.4, No.1, pp.63-75, Mar. 2018.

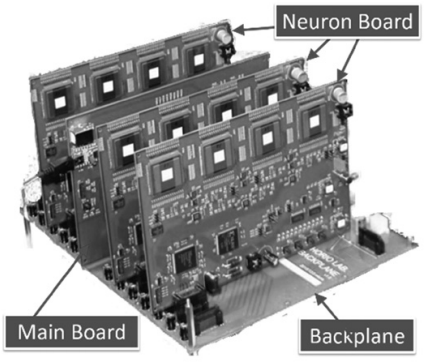
Soft Computing Integrated System

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 spintronics devices/circuits for adaptive non-volatile synaptic connections. At the same time, we are developing a massively-parallel brainmorphic (brainware) 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), IEICE NOLTA Lifetime Achievement Award (2016), and Fellow, IEICE (2018).

[Papers]

[1] T. Orima and Y. Horio, "An improved parameter value optimization technique for the reflectionless transmission-line model of the cochlea," Journal of Robotics, Networking and Artificial Life, vol. 4, no. 1, pp. 49-52, DOI:10.2991/jrnal.2017.4.1.11, 2017.

[2] Y. Horio, "Towards a brainmorphic computing paradigm and a brain/body whole organism computation system," in Proc. of RISP Int. Workshop on Nonlinear Circuits, Communications and Signal Processing, pp. 703-192, 2018.

[3] Y. Horio, "Towards a neuromorphic computing hardware system," in Proc. of International Symposium on Nonlinear Theory and Its Applications, pp. 189-192, 2017.

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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.

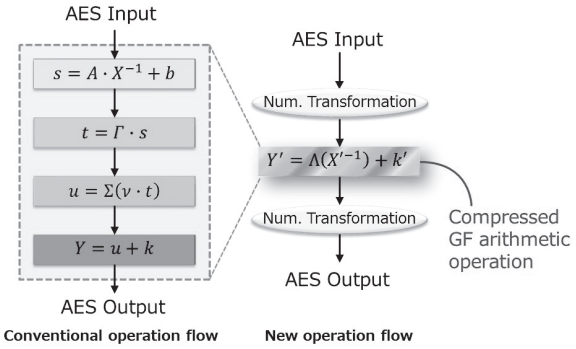


Fig. 1: New operation compression technology for AES cryptographic processing.

[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 RIEC Award in 2012, the Best Symposium Paper Award at IEEE International Symposium on Electromagnetic Compatibility (EMC 2013) in 2013, the Best Paper Award at the IACR Conference on Cryptographic Hardware and Embedded Systems (CHES 2014) in 2014, the JSPS Prize in 2018, and the Ichimura Prize in Science for Distinguished Achievement in 2018.

[Papers]

[1] Rei Ueno et al., "Toward More Efficient DPA-Resistant AES Hardware Architecture Based on Threshold Implementation," COSADE 2017, LNCS 10348, pp. 50—64, Springer, April 2017.
[2] Manami Suzuki et al., "Multiple-Valued Debiasing for Physically Unclonable Functions and Its Application to Fuzzy Extractors," COSADE 2017, LNCS 10348, pp. 50—64, Springer, April 2017.
[3] Rei Ueno et al., "A Systematic Design of Tamper-Resistant Galois-Field Arithmetic Circuits Based on Threshold Implementation with (d+1) Input Shares," ISMVL 2017, pp. 136—141, IEEE, May 2017.
[4] Noriyuki Miura et al., "A 2.5ns-Latency 0.39pJ/b 289 μ m^2/Gb/s Ultra-Light-Weight PRINCE Cryptographic Processor," 2017 Symposium on VLSI Circuits, Digest of Technical Papers, pp. C266-C267, June 2017.
[5] Daisuke Ishihata et al., "Enhancing Reactive Countermeasure against EM Attacks with Low Overhead," 2017 IEEE International Symposium on Electromagnetic Compatibility, pp. 399-404, August 9, 2017.

New Paradigm VLSI System Research Group

Realization of a New-Paradigm VLSI-Computing World

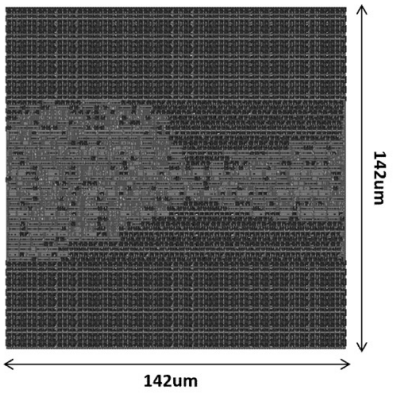


Fig. 1. Memory-access controller for compact & low-power MTJ-based nonvolatile logic LSI. The proposed technique enables to suppress the frequency of memory access (50MHz) while maintaining the data supply rate to the CPU (100MHz).

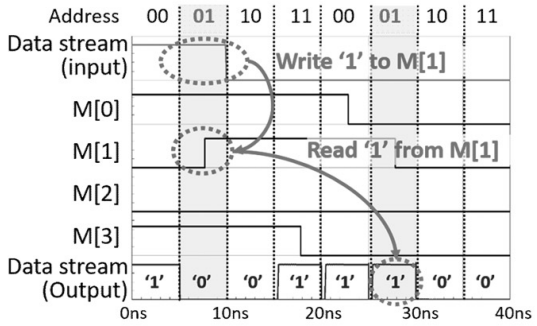


Fig. 2. Simulated waveforms of a shift operation based on memory addressing. Reading/writing nonvolatile devices corresponding to a memory address makes it possible to reduce the number of writing for a 1-bit shift operation to 1. As a result, the proposed method achieves a 93% reduction in power in comparison with a conventional method.

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 the memory-access controller for compact & low-power Magnetic Tunnel Junction (MTJ)-based nonvolatile logic LSIs (Fig. 1) and LUTs with shift operations based on memory addressing (Fig. 2).

[Staff]

*Affiliation: Frontier Research Institute for Interdisciplinary Sciences (Prof. Hanyu is the mentor of them.)

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] N. Onizawa, et al., "Area/Energy-Efficient Gammatone Filters Based on Stochastic Computation," IEEE Transactions on Very Large Scale Integration (VLSI) Systems, vol. 25, No. 10, pp. 2724-2735, Oct. 2017.

[2] A. Ardakani, et al., "VLSI Implementation of Deep Neural Networks Using Integral Stochastic Computing," IEEE Transactions on Very Large Scale Integration (VLSI) Systems, vol. 25, No. 10, pp. 2688-2699, Oct. 2017.

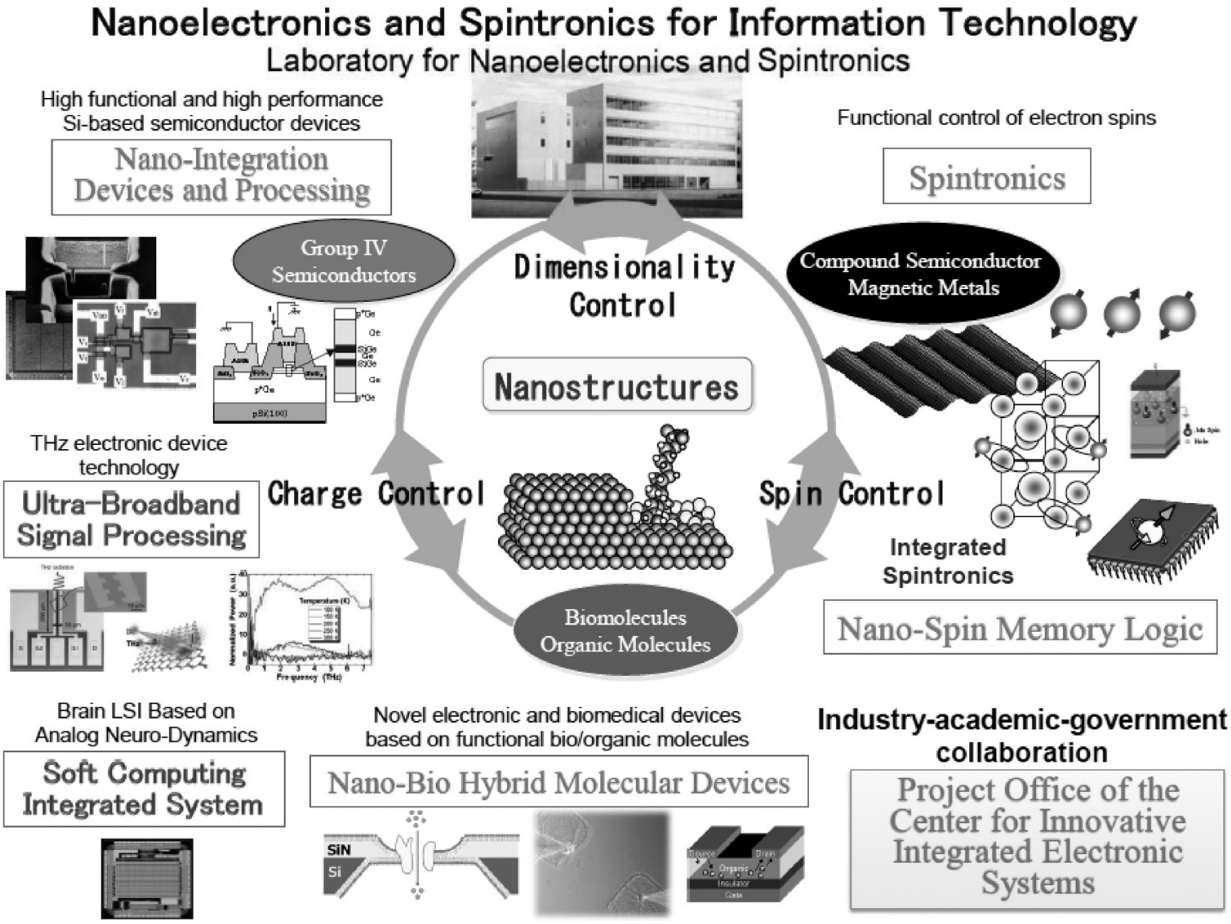
[3] N. Onizawa, et al., "Sudden Power-Outage Resilient In-Processor Checkpointing for Energy-Harvesting Nonvolatile Processors," IEEE Transactions on Emerging Topics in Computing (TETC), vol. 5, No. 2, pp. 151-163, Apr.-Jun. 2017.

Contact to Professor Takahiro HANYU : hanyu@riec.tohoku.ac.jp

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, Spintronics and Nano-Bio Hybrid 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 2017

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 learning method for qubit networks. We applied it to an associative memory problem and confirmed that a modified Hebb rule works efficiently.

(2) By using low-energy ECR plasma CVD without substrate heating, in addition to epitaxial growth of heavily B-doped and high carrier-mobility Si film (46 cm^2 V^{-1} s^{-1} at $2.5x10^{19}$ cm^{-3}), effective suppression of reverse-bias current in a pn junction with the B-doped Si has been demonstrated.

(3) Toward the development of a neuromorphic vision processing system, we verified the operation of a local motion detection LSI inspired by motion stereo vision in human vision system. We confirmed that a test system, which is composed of a camera, an FPGA board, and the local motion detection LSI, can successfully detect optical flow in a live video at 30 fps.

(4) To study the relation between the structure of neuronal circuitry and its temporal-spatial dynamics, we investigated the effects of the modular structure of neuronal circuitry on its firing property. It has been clarified that complex dynamics, in which various synchronized states are mixed, is realized for the case when the interaction between modules is moderate.

● **Soft Computing Integrated System (Y. Horio)**

(1) We proposed a chaotic reservoir network composed of chaotic neurons, which is applicable to the reference-self system in the brain-body whole organism computing paradigm. We confirmed feasibility of the proposed chaotic reservoir network through chaotic time-series predictions.

(2) For a dynamics/algorithm sub-conscious/conscious hybrid computer system, we designed and fabricated two switched-current chaotic neural network integrated circuit chips with TSMC 65 nm CMOS and ROHM 180 nm CMOS processes.

(3) We conducted basic study on the reward modulated STDP learning rule for spin orbit torque synaptic devices.

(4) We used ordered entropy to evaluate the dynamics of a reservoir network through a chaotic time-series prediction.

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) Revealing the potential of Fe-inserted Fe-V/MgO magnetic tunnel junction to show high interfacial magnetic anisotropy while lowering magnetization and magnetic damping,

(2) Observation of electric-field effect on exchange stiffness of CoFeB/MgO magnetic tunnel junction through spin-wave resonance, which is in consistent with previous conclusions drawn from domain-pattern observation, (3) Achievement of world-highest Curie temperature, 250 K, in Cr-doped Sb_2Te_3 topological insulator prepared by molecular beam epitaxy, (4) Clarification of enhancement of spin-orbit torque switching efficiency with increasing stacking number of Co/Pt multilayer that processes high magnetic anisotropy, (5) Showing different asteroid curves in two nanoscale magnetic tunnel junction prepared by different conditions, which can be attributed to a different degradation level of magnetic anisotropy near the pattern edge, (6) Quantification of spin-orbit torque and Dzyalloshinskii-Moriya interaction in PtMn/[Co/Ni] structure and comparison with Pt/[Co/Ni] systems, showing similar sign and magnitude between the samples for spin-orbit torque and different sign and magnitude between the samples for Dzyalloshinskii-Moriya interaction, (7) Achievement of unexplored single-digit-nanometer magnetic tunnel junction with high thermal stability factor and capability of spin-transfer torque switching by revisiting shape anisotropy, (8) Revealing time and spatial evolution of spin-orbit torque-induced magnetization switching in W/CoFeB/MgO heterostructure by investigating size and pulse width dependence of the switching properties, (9) Showing contrasting size dependence of magnetic anisotropy for two magnetic tunnel junctions describe in (5); one is explained by considering size dependence of shape anisotropy, (10) Establishment of a scheme to evaluate reliable thermal stability factor without acceleration by magnetic field or current, and discussion on the factors governing the temperature dependence of the thermal stability factor of CoFeB/MgO magnetic tunnel junction determined by the established method.

● **Ultra-Broadband Signal Processing (T. Otsuji and A. Satou)**

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 2017FSY.

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 as well as amplified spontaneous broadband emission ranging from 1 to 7.6 THz at 100K by using our original distributed feedback dual-gate device structure.

2. Development of photonics-electronics convergence mixers

To realize the carrier frequency down-conversion from optical to wireless data signals, which is one of key technologies in future photonics-electronics convergence networks, we study the photonic double-mixing functionality of InGaAs-channel high-electron mobility transistors (InGaAs-HEMTs). This fiscal year, we demonstrated the frequency down-conversion of 1.5-μm optical data signal with 12-GHz ASK/BPSK modulation to 22.5-GHz millimeter-wave IF data signal using an InGaAs-HEMT.

Nano-Bio Hybrid Molecular Devices

● Nano-Bio 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.

1. Reconstitution of cell-free synthesized ion channels in microfabricated Si chips
   We reported on optimized nano- and micro-structures for mechanically stable bilayer lipid membranes (BLMs) using Si microfabrication techniques. We also succeeded in reconstitution of cell-free synthesized wild type hERG channels into the BLMs and recording their activity at the single-channel level.
2. Reconstitution of artificial neuronal networks
   By growing primary neurons on a microfabricated coverslip, we investigate structure-function relationships in neuronal networks. We also use computational models to provide graph theoretical interpretations on experimental data. Our recent work identified the influence of intra-modular connectivity on global synchronizability in modular networks.
3. Charge transfer in organic solar cells and novel structure for perovskite solar cells
   The charge transfer mechanism in organic solar cells has been studied by a simple displacement current technique. To improve the performance and reduce the cost of perovskite solar cells, we proposed a new structure and verified the applicability of the new structure using numerical simulation technique.

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.

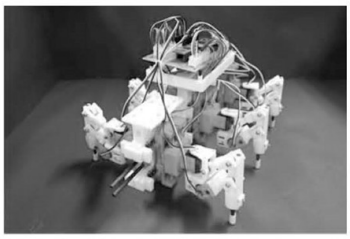
The technology developed in the Laboratory is expected to enhance the research carried out in the four Divisions of the Institute, and the research conducted in the Divisions, in turn, is expected to provide scientific basis for the information technology developed in the Laboratory.

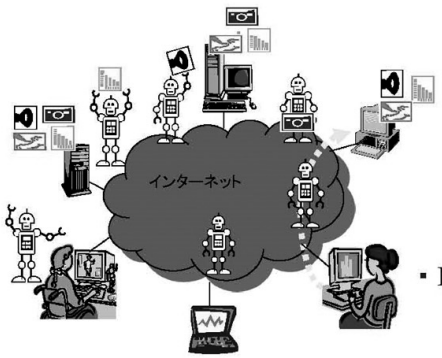
Physical and Adaptive Hardware Environment

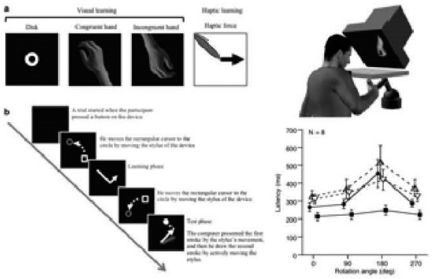
Seamless Fusion of Real World and Multi-Modal Computing

・Brain-Like Computing

(Brain Architecture)







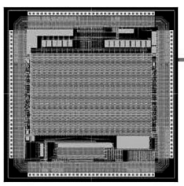
・ Real-World Dynamical Intelligence

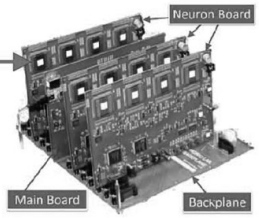
(Real-World Computing)

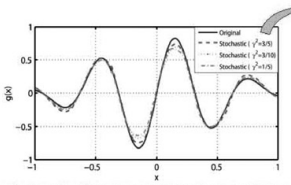
・ Higher-Order Multimodal Perception and Information Generation

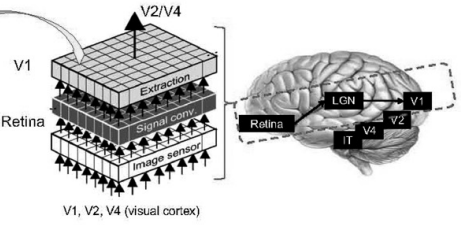
(Recognition and Learning Systems)

Hardware Environment with Massively Parallel Brain LSI









・ Brain LSI Based on Analog Neuro-Dynamics

(Soft Computing Integrated System)

・ Stochastic computation for Brainware LSI system

(New Paradigm VLSI System)

[Research Target]

Real-World Computing Section: The main contributions achieved in 2017 are summarized as follows: (1) we have proposed a decentralized control scheme for versatile locomotion of snakes; (2) we have developed a brittle star-like robot that can immediately adapt to physical damage; (3) we have proposed a decentralized control mechanism for the interlimb coordination underlying hexapod locomotion; (4) we have developed a myriapod robot that can reproduce millipede locomotion; (5) we have proposed a minimal model for the body-limb coordination in quadruped 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 2017 are summarized as follows: (1) we have demonstrated the applicability of *Tegotae*-based control scheme, which we proposed previously, to various types of locomotion such as hexapods, earthworms, and snakes via simulations and real-world experiments with robots; (2) we have succeeded in developing a brittle-star like robot that can immediately adapt to physical damage. This result has been advertised in the press; (3) we have succeeded in formulating body-limb coordination mechanisms of quadruped locomotion, and applied it to other animals such as centipedes and sea roaches.

New Paradigm VLSI System Section: The major contributions achieved in 2017 are summarized as follows: we have successfully achieved to (1) design and evaluate an MTJ (Magnetic Tunnel Junction)-based nonvolatile FPGA (Field-Programmable Gate Array) with a "data-shift" function, where only one-bit data stored into an LUT (Lookup Table) circuit is updated in this operation, (2) to design an interface circuit controlling data transmission between CPU and nonvolatile memory in MTJ-based nonvolatile microcontroller LSI, (3) and to design a small-area and low-power deep-learning LSI based on stochastic computing. The above research results have reported 9 academic journal papers such as IEEE Trans. VLSI Systems, and 13 peer-reviewed international conference papers.

Recognition and Learning Systems Section: The visual system constructs representations of the world through repeated observations as suggested by contextual cueing effect (CCE). CCE is the learning effect of spatial layouts revealed by reaction time shortening in visual search due to repeating presentations of the same layouts. We built a model that predicts reaction time shortening by CCE, using reinforcement learning of relationships between the target location and global features of layouts. The relationship is expressed by mapping probability of the target location on each layout. The probability map is used to weight the saliency map obtained based on visual features in order to predict where to attend for searching a target. With successful learning, the probability map is expected to show the largest probability at the actual target location. The learning speed depends on a parameter of reinforcement and we obtained the parameter for the best prediction of psychophysical experiments.

Soft Computing Integrated System Section: Results of this year include the followings. (1) We proposed a chaotic reservoir network composed of chaotic neurons, which is applicable to the reference-self system in the brain-body whole organism computing paradigm. We confirmed feasibility of the proposed chaotic reservoir network through chaotic time-series predictions. (2) For a dynamics/algorithm sub-conscious/conscious hybrid computer system, we designed and fabricated two switched-current chaotic neural network integrated circuit chips with TSMC 65 nm CMOS and ROHM 180 nm CMOS processes. (3) We conducted basic a study on the reward-modulated spike timing dependent plasticity (STDP) learning rule for spin orbit torque synaptic devices. (4) We used ordered entropy to evaluate the dynamics of a reservoir network through a chaotic time-series prediction.

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 developed a model of the contextual cueing effect using reinforcement learning. The visual system constructs representations of the world through repeated observations as suggested by contextual cueing effect (CCE). CCE is the learning effect of spatial layouts revealed by reaction time shortening in visual search due to repeating presentations of the same layouts. We built a model that predicts reaction time shortening by CCE, using reinforcement learning of relationships between the target location and global features of layouts. The relationship is expressed by mapping probability of the target location on each layout. The probability map is used to weight the saliency map obtained based on visual features in order to predict where to attend for searching a target. With successful learning, the probability map is expected to show the largest probability at the actual target location. The learning speed depends on a parameter of reinforcement and we obtained the parameter for the best prediction of psychophysical experiments. Second, we measured how movements of body parts affect 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 strength of the flash-lag illusion is reduced when participants move their own hand. This suggests that bodily attention is modulated by body part movements.

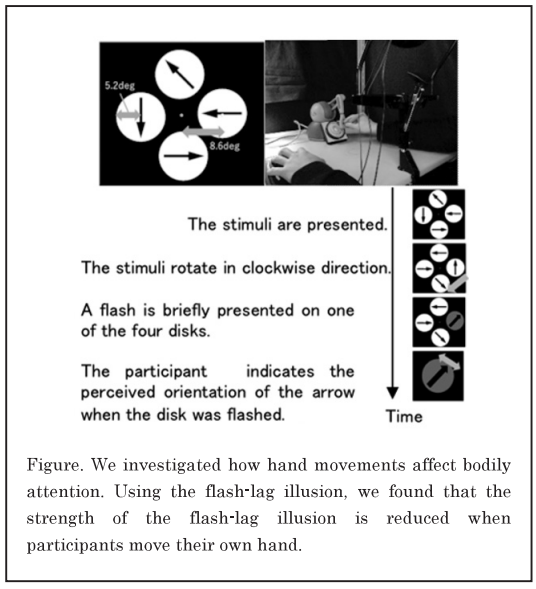


Figure. We investigated how hand movements affect bodily attention. Using the flash-lag illusion, we found that the strength of the flash-lag illusion is reduced when participants move their own hand.

[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 worked as an Associate Professor from July, 2014. He is a Professor of Graduate School of Information Sciences, Tohoku University from February, 2018.

[Papers]

1. Shioiri, S., Yuan, Z., Matsumiya, K., Kuriki, I.: "Modeling the learning process of object locations in natural scenes", The 13th Asia-Pacific Conference on Vision (APCV2017), Tainan, Taiwan, July 13-17, 2017.
2. Nonomura, M., Tseng, C.H., Matsumiya, K., Kuriki, I., Shioiri, S.: "Shift of visual attention to the illusory hand location", The 13th Asia-Pacific Conference on Vision (APCV2017), Tainan, Taiwan, July 13-17, 2017.

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 planned on matching with both basic technologies in the University and application in the Industry. Combination of the technologies of the University and Industry makes practical technologies with availability for the commercial products. The center actively accelerates to obtain the intellectual properties generated from the development of practical technology to the Industry. This year, the center was reformed and two divisions are newly established. One is "Interdisciplinary Collaboration Research Division" and it consists of one project, "Research project of human value estimation of multimodal information based on informatics paradigm to manage both quality and value". Another is "Challenging and Exploratory Research Division" and it consists of two projects, "Interactive drone content for entertainment / wildlife symbiosis" and "Wireless IoT Technology for a safe & secure mediciation management system". Former "Technology Development Division" is renamed to "Industry-Academia-Government-Collaboration Research and Development Division" and it consists of mobile wireless technology group. Presently, following two projects are being carried out in the mobile wireless technology group.

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 integrated with second harmonic feedback circuit by using 0.18-μm CMOS process. The fabricated power amplifier satisfied the target values of saturated output RF power and shows 3.2% improvement of power added efficiency by the harmonic feedback. These results show the feasibility of CMOS PAs for mobile terminal applications.

2. R&D on Technologies to Densely and Efficiently Utilize Radio Resources of Unlicensed Bands

From this year, the mobile wireless technology group has started a new R&D project "R&D on Technologies to Densely and Efficiently Utilize Radio Resources of Unlicensed Bands in Dedicated Areas" supported by the Ministry of Internal Affairs and Communications. In this project, we are going to develop a real-time frequency monitor to avoid the interference between different wireless systems in dedicated areas such as factory or office. This year, we have developed an 800MHz-6GHz broadband undersampling S/H CMOS IC for the real-time frequency monitor.

[Staff]

Director: Hiroaki Muraoka, Professor

Makoto Furunishi, Visiting Professor
Hiroshi Matsuoka, Visiting Professor

Industry-Academia-Government-Collaboration Research and Development Division (Mobile Wireless Technology Group)

Noriharu Suematsu, Leader, Professor
Suguru Kameda, Associate Professor
Mizuki Motoyoshi, Assistant Professor
Hiroshi Okazaki, Visiting Professor

Interdisciplinary Collaboration Research Division

Satoshi Shioiri, Project Leader, Professor

Challenging and Exploratory Research Division

Yoshifumi Kitamura, Project Leader, Professor
Suguru Kameda, Project Leader, Associate Professor

IT21 Center Mobile Wireless Technology Group

Dependable Air

Noriharu Suematsu, Professor (Project Leader)
Suguru Kameda, Associate Professor
Teruo Ohnishi, Visiting Professor

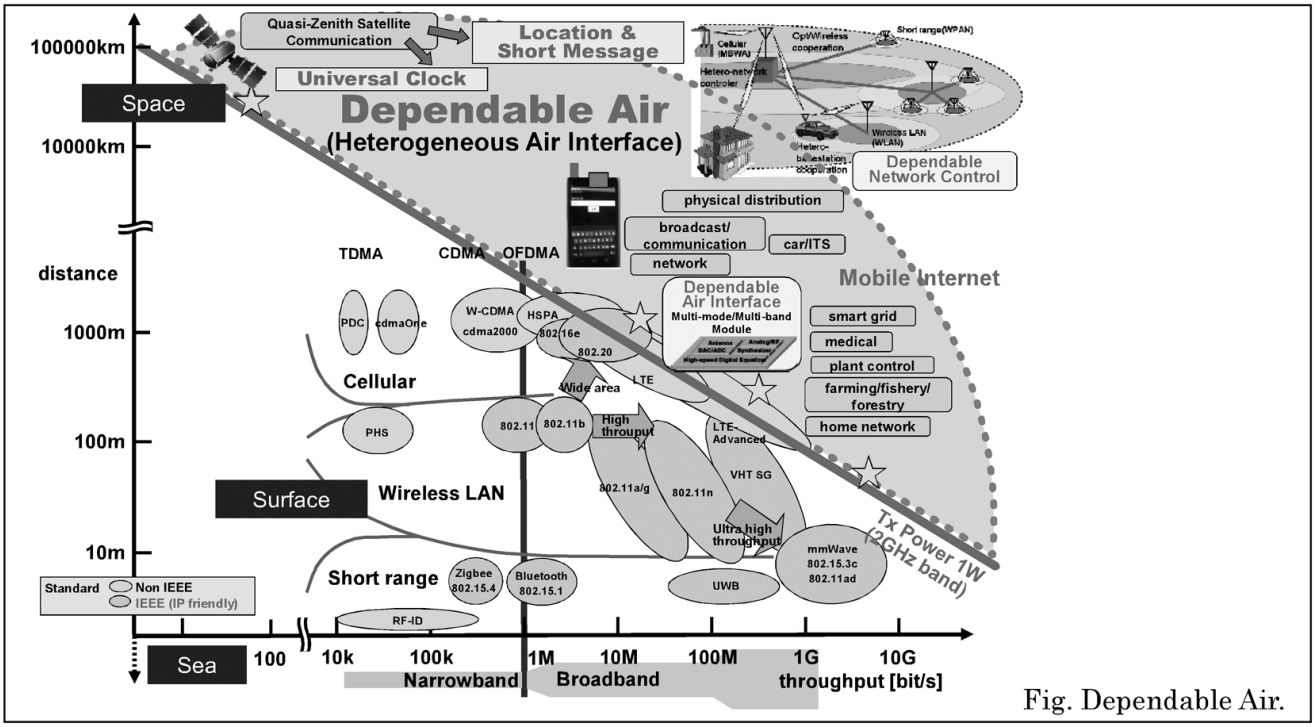


Fig. Dependable Air.

[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. To realize this concept, 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. From this year, the group has started a new R&D project "R&D on Technologies to Densely and Efficiently Utilize Radio Resources of Unlicensed Bands in Dedicated Areas" supported by the Ministry of Internal Affairs and Communications.

[Staff]

Professor: Noriharu Suematsu, Ph.D
Associate Professor: Suguru Kameda, Ph.D
Visiting Professor: Teruo Ohnishi, Ph.D

[Papers]

[1] N. Suematsu, T. Owada, T. Koizumi, M. Motoyoshi, and S. Kameda, "A Ku-Band Direct RF Undersampling Receiver with an Intermittent-Mode Amplifier," 2017 IEEE International Symposium on Radio-Frequency Integration Technology (RFIT 2017), Seoul, Korea, August 2017.

Contact to Professor Noriharu SUEMATSU : suematsu@riec.tohoku.ac.jp

Management Office for Safety and Health

Realizing and Maintaining a Safe and Comfortable Environment to Support Research

[Research Target and Activities]

Safety and health seminar

First aid training course

1. Outline of the Management Office for Safety and Health

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

2. Activities by the Management Office for Safety and Health

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

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

[Staff]

Manager: Takahiro Hanyu, Professor

Deputy Manager: Yoichi Uehara, Professor

Nobuyuki Sato, Assistant Professor

Maho Abe, Technical Staff　　Haruka Takahashi, Clerk

Flexible Information System Center

Development and Management of Flexible Information System

[Research Target and Activities]

Figure 1 RIEC network system

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.

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.

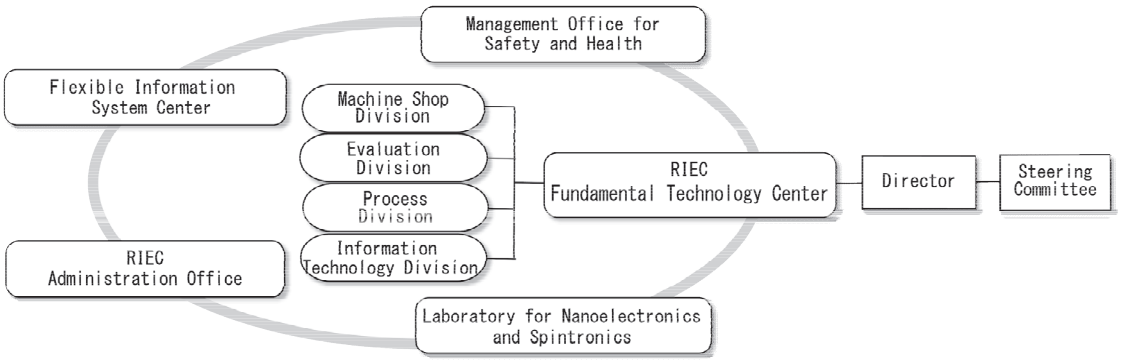
[Staff]

(1) Steering Committee
Professor: Tetsuo Kinoshita, Dr., Yôiti Suzuki, Dr., Yoshihito Toyama, Dr., Masafumi Shirai Dr., Atsushi Ohori, Dr., Takuo Suganuma, Dr.

(2) Regular Staff
Associate Professor: Gen Kitagata, Dr.
Assistant Professor: Kazuto Sasai, Dr.
Technical Official: Masahiko Sato, Kenji Ota
Technical Support Member: Mutumi Syutou, Riho Ooizumi

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

2. Evaluation Division

21 laboratories utilized evaluation and measurement apparatuses for shared usage (the utilization time was 7226 hours in total), and furthermore there was utilization from the outside of university. Glass processing products of 6 were supplied. 3976 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 174 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.

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

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 confirmed that visual and auditory attention can be measured in the multi-sensory space 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. 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 this purpose, nitrogen (N)-polar GaN materials are intensively studied to apply them to high-electron mobility transistors (HEMTs). By optimizing the crystal growth conditions, our group has realized GaN/AlGaN heterostructures with smoothest surface ever reported. As a result, an anisotropy of transistor characteristics, which is a well-known issue in the N-polar HEMTs, has been resolved.

[Yotta Informatics Research Group]

The amount of information is rapidly increasing, and is projected to reach one yotta bytes, one trillion times of one Tera-bytes, or 10^{24} bytes by 2030. The information is too large to be handled by conventional ICT technology. Therefore a paradigm shift in information processing is indispensable. In this group, we aim to develop new informatics, which can manage the “quality” of information as well as the information “amount”. In 2017 regular 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 advanced 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 by various researchers from the viewpoints of software constitutive theory, system security, hardware security, circuit architecture, next-generation microprocessor, and so on. In this year, we discussed and confirmed our goal and research direction with several seminars and meetings.

[Brainmorphic Nano-Devices and Circuits Research Group]

Brain-inspired hardware systems have been actively developed recently. However, a big break-through to the true brain-like system has not been reached yet. This research group, established in this year, aims at development and implementation of novel brainmorphic computational hardware that reproduces the bio-physics and dynamics in the brain directly through dynamics and physics of nano-devices and ultra-low-power integrated circuits based on the latest physiological knowledge. As the first year of this research, we had 9 meetings to clarify status and problems of current brain-inspired hardware from broad perspective that includes brain science, spintronics, analog/digital integrated circuits, cultured neurocyte, and nonlinear complex dynamics. We also discussed a basic strategy and a future plan to remove the partitions among these research areas, and to collaborate together in creating new brainmorphic hardware.

[Research Group for Advanced Wireless IoT]

The aim of this research group is to propose a novel concept of Internet of Things (IoT) total solution. In the real IoT era, low latency / high data rate / dense wireless connection will be required as a last 1 meter mobile / flexible network. In order to realize this last 1 meter mobile / flexible wireless network, millimeter-wave (MMW) / sub-MMW will be used to reduce the interference between the dense / various wireless networks. This year, the pros. and cons. of MMW/ sub-MMW usage has been discussed.

Center for Spintronics Integrated Systems (CSIS)

＜About the Center＞

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

Organization :

- Director : Hideo Ohno (Professor and Director of RIEC)
- Number of Researchers : 26 (including 17 concurrent appointments)

Research Target : CSIS has been advancing the following program 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 **2014/10/2～2017/11/30** and Prof. Tetsuo Endoh **2017/12/1～**)" in ImPACT program (Program Manager: Prof. Masashi Sahashi) of CSTI

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 2017＞

(1) Development of magnetic tunnel junction (MTJ) stacks having low *RA* (~ 4 $\Omega\mu m^2$) and low damping (~ 0.004). This technology contributed to realization of high thermal stability and demonstration of spin transfer torque magnetization reversal for unprecedented single-digit-nanometer MTJs, (2) Establishment of new method to evaluate edge damage in MTJ from asteroid curve by micromagnetic simulation. This evaluation method is effective for obtaining development guidelines for MTJ integration process, (3) Development of fabrication process of nanoscale spin orbit torque (SOT) device and demonstration of magnetization reversal at 1 ns in 50 nmϕ SOT device consisting of antiferromagnetic PtMn and Ni/Co ferromagnetic multilayer, (4) Proposal of self-terminated circuit technology to autonomously detect write completion of MTJ device in order to reduce the extra current caused by device property distribution, (5) Proposal of high efficiency memory access technology in order to realize relaxation of required specifications to circuit blocks and high-speed data reading by suppressing extra memory access by using the property of the target CPU, (6) Proposal of multi-function & low energy consumption technology of operation circuit (nonvolatile FPGA).

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 2017, 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 demonstrated the messaging function with "relay by smart device" in Sendai city center. The research results produced by the promoted projects were presented at the Disaster Reconstruction and Regeneration Research Symposium of Tohoku University. Our activities were also described in ROEC Newsletters published in 2017.

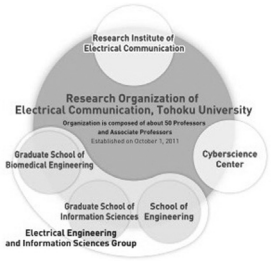


Fig.1 Research Organization of Electrical Communication.

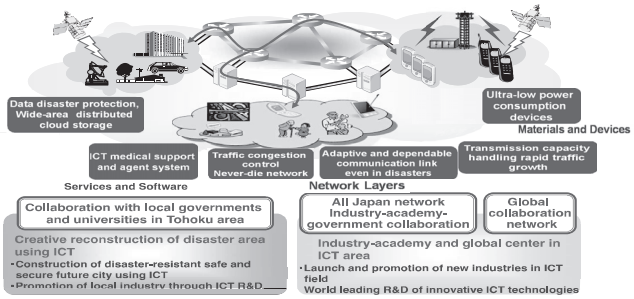


Fig.2 Overview of ICT Reconstruction Project.

[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] H. Nishiyama, et al., "On OFDM-Based Resource Allocation in LTE Radio Management System for Unmanned Aerial Vehicles (UAVs) (Invited Paper)", 2017 IEEE 86th Vehicular Technology Conference (VTC2017 fall), Toronto, Canada.
[2] T. Otsuji, et al., "Sub-THz photonic frequency conversion using optoelectronic transistors for future fully coherent access network systems," Proc. SPIE, vol. 9772, pp. 977204-1-9, 2016. (invited) DOI: 10.1117/12.2209211
[3] K. Kasai, et al.,"80 Gbit/s/ch, 256 QAM Digital Coherent Optical Transmission System with Injection-Locking for Next Generation Mobile Fronthaul Network," ECOC 2017, Th.1.B.5, September 2017.

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: 86 (including appointments across Graduate School of Engineering, Graduate School of Information Sciences, RIEC 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 FY2017＞

CIES has managed the “CIES consortium” which consists of seven industry–academic collaborations, major national projects (JST-ACCEL, JST-OPERA, CSTI-ImPACT, JSPS Core-to-Core and NEDO projects) and community-based cooperation projects in cooperation with various international and domestic companies from material, equipment, devices and system aiming for the practical applications of innovative core technologies created by Tohoku University. Companies participating in the CIES consortium have been steadily increasing 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 Sendai City)”.

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 in the development of spintronics integrated

circuits, which is compatible with world-class companies' fabs. In STT-MRAM development, we have continuously developed the core technologies from materials and devices based on scientific understanding to integrated processes and circuits, and successfully demonstrated innovative nonvolatile artificial intelligence (AI) processors and commercialized the evaluation equipment, etc. In addition, in the development of the GaN on Si power devices, new members have joined, and the development of the power module technology and innovative power electronics technology have been launched. In the regional collaboration, we promoted a technology matching program for regional and local companies with cooperation of Miyagi Prefecture, Iwate Prefecture etc, which resulted in a progress of commercialization and contributed to rebuild the Tohoku area and assist the region.

In order to establish world leading R&D base for integrated electronic systems and AI hardware, we will continue to create innovative core technologies and contribute to the industry and the enhancement of global competitiveness by the practical applications, and "new creation and innovation" through global and regional partnership, in addition to playing a role as the research center "core research cluster" in recognition as "Designated National University".

Center for Spintronics Research Network (CSRN)

＜Overview＞

Establishment: April 1, 2016

Organization: Director: Hideo Ohno (Director, Professor, RIEC)
Number of academic members: 63 (including 4 full-time members and the other concurrent members from Graduate School of Science, Graduate School of Engineering, IMR, RIEC, IMRAM, AIMR, CSIS, 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 42 cooperative research projects to promote collaborations with other spintronics researchers. The collaborators belong 37 institutions in Japan and 13 overseas institutions (in 10 countries). For detail, see the following URL: http://www.csrn.tohoku.ac.jp/

・Academic Meetings

As a part of activity based on MOU on academic exchange between CSRN and Singapore Spintronics Consortium (SG-Spin), the first Workshop was held in Sendai on February 20, 2018. For promoting exchange and fostering human resources of spintronics researchers, CSRN jointly hosted international conferences, workshops, and schools (18 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 FY2017＞

In FY2017, 10 new students joined the program and 68 students in total learned the fundamental and specialized subjects and joined long-term internship at domestic corporations and foreign institutions.

The 3rd Symposium between the MD program and Ambitious Leaders's program (Hokkaido University) was held in Zao during May 19-20, 2017. The symposium was organized by students of MD program. Workshops, poster sessions and research reports were carried out during the symposium to promote mutual exchange between students of two programs.

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 FY2017＞

In FY2017, 15 invited researchers gave lectures at the GP-Spin Seminar during their stays in Tohoku University.

The Lorraine-Mainz-Tohoku Joint Seminar “Prospect of Future Spintronics” organized by students of GP-Spin was held during October 31-November 2, 2017 at Tohoku University. World-leading 4 researchers in spintronics invited from Lorraine University, Johannes Gutenberg University Mainz and Tohoku University gave special lecturers. Other speakers including students also gave exciting talks including the topics related to their new research results.

The 43rd Reimei/GP-Spin/ICC-IMR International Workshop on New Excitations in Spintronics was held at Tohoku University during January 10-12, 2018.

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 2017＞

1. Meeting and discussions by the all project members

   Two meetings were held, 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. Symposium

   We organized a symposium, which consisted an invited talk by Italian professors digital museum and progress reports of project members.

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. Funds

   1) Subsidy by MEXT (Strengthening the functions of national university) for Yotta Informatics Research Center.

   2) Scope (MIC) Training type research and development for small and medium-sized enterprises.

   Project: Research and development of AI-based testing system for electrical circuit (collaboration with Tohoku Electronic Industrial Co. Ltd.), 2017

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 2017

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H27/A02	Basis Establishment of Plasma Nanobio-Medicine	KANEKO Toshiro Graduate School of Engineering, Tohoku University	HIRANO Ayumi
H27/A03	Quantum Heterostructure Formation of Group-IV Semiconductors and Control of Electronic Properties Utilizing Atomically-Controlled Plasma CVD	SAKURABA Masao Research Institute of Electrical Communication, Tohoku University	SAKURABA Masao
H27/A04	Next-generation device research using operando spectromicroscopy	FUKIDOME Hirokazu Research Institute of Electrical Communication, Tohoku University	FUKIDOME Hirokazu
H27/A05	Development of novel quantum light sources for quantum info-communication	EDAMATSU Keiichi Research Institute of Electrical Communication, Tohoku University	EDAMATSU Keiichi
H27/A06	Nano-scale Geometrical Control and Optical Properties of a Single Metal Nanostructure	KATANO Satoshi Research Institute of Electrical Communication, Tohoku University	KATANO Satoshi
H27/A08	Studies on resonant tunneling THz signal generators having low phase noise properties	MAEZAWA Koichi Graduate School of Science and Engineering, University of Toyama	OTSUJI Taiichi
H27/A09	A study of carrier conversion system between optical and wireless signal frequency domain for future full-coherent access networks	YOSHIMOTO Naoto Faculty of Science and Technology, Chitose Institute of Science and Technology	OTSUJI Taiichi
H27/A10	A research on reflectarray using metamaterial for propagation improvement in M2M communications	MARUYAMA Tamami Department of Production Systems Engineering, National Institute of Technology, Hakodate College	SUEMATSU Noriharu
H27/A11	An Empirical Study on SDN-based Networking System based on Changes in User's Physiological Indexes	OMATA Masaki Graduate Faculty of Interdisciplinary Research, Yamanashi University	KITAGATA Gen

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H27/A12	Effects of self-movements on perception of the surrounding world	**TERAMOTO Wataru** Faculty of Letters, Kumamoto University	**SAKAMOTO Shuichi**
H27/A13	Studies on relationship between perception of monaural sound and head-related transfer function	**MORIKAWA Daisuke** Graduate School of Advanced Science and Technology, Japan Advanced Institute of Science and Technology	**SAKAMOTO Shuichi**
H27/A16	Workshop and Practical Study on the Handing Down of Disaster Experiences from the Perspective of Information Communication Technology	**SATO Shosuke** International Research Institute of Disaster Science, Tohoku University	**Jorge Alberto Trevino Lopez**
H27/A17	Influence of synchrony perception on sense of presence and verisimilitude in multimodal environment	**OHTANI Tomoko** Art Media Center, Tokyo University of the Arts	**Jorge Alberto Trevino Lopez**
H27/A18	Influence of speaker's movie of speech utterance on serial recall task	**OHTANI Tomoko** Art Media Center, Tokyo University of the Arts	**SAKAMOTO Shuichi**
H27/A20	Research on measurement technologies of earthquakes, tsunami, and crustal deformation using an optical-fiber network	**ARAYA Akito** Earthquake Research Institute, The University of Tokyo	**NAKAZAWA Masataka**
H27/A21	Hardware Technology for Brain Computation	**SATO Shigeo** Research Institute of Electrical Communication, Tohoku University	**SATO Shigeo**
H27/A23	Research of Multimodal Agent Framework for Symbiotic Computing	**UCHIYA Takahiro** Information Technology Center, Nagoya Institute of Technology	**KINOSHITA Tetsuo**
H27/A24	Study on knowledge acquisition and utilization for the diversifying information networks.	**UEDA Hiroshi** Academic Center for Computing and Media Studies, Kyoto University	**KINOSHITA Tetsuo**
H27/A25	Development of a system architecture and infrastructure technology for the Smart Community	**FUKUDA Akira** Faculty of Information Science and Electrical Engineering, Kyushu University	**KINOSHITA Tetsuo**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H27/A26	Empirical Researches for introducing ubiquitous systems into the actual life	**ARAKAWA Yutaka** Graduate School of Information Science, Nara Institute of Science and Technology	**TAKAHASHI Hideyuki**
H27/A27	Research on olfactory multimodal information processes in humans.	**SAKAI Nobuyuki** Graduate School of Arts Letters, Tohoku University	**SAKAMOTO Shuichi**
H28/A01	Exploration of phase change phenomena of nanometer-scale materials and their applications to opto-electronic devices	**KUWAHARA Masashi** Electronics and Photonics Research Institute, National Institute of Advanced Industrial Science and Technology	**UEHARA Yoichi**
H28/A02	Study on High Power Amplifier with InGaAs HEMTs with Field Plate	**UMEDA Yohtaro** Faculty of Science and Technology, Tokyo University of Science	**SATOU Akira**
H28/A03	Electroluminescence from Si-Ge based Quantum Dots	**MIYAZAKI Seiichi** Graduate School of Engineering, Nagoya University	**SATO Shigeo**
H28/A04	Improvement of Superconducting Detectors and Readouts	**ISHINO Hirokazu** Graduate School of Natural Science and Technology, Okayama University	**SATO Shigeo**
H28/A05	Study on a local field effect of localized electronic polarizations in semiconductors	**MITSUMORI Yasuyoshi** Research Institute of Electrical Communication, Tohoku University	**MITSUMORI Yasuyoshi**
H28/A06	Quantum emitters coupled to a chiral nanowaveguide	**Sadgrove Mark Paul** Research Institute of Electrical Communication, Tohoku University	**Sadgrove Mark Paul**
H28/A08	Study on Brainware Architecture	**KANOH Toshiyuki** Central Research Laboratories, NEC Corporation	**HORIO Yoshihiko**
H28/A09	Investigation of quantitative evaluation method for developing a tool to support intellectual creation activities	**UEOKA Ryoko** Faculty of Design, Kyushu University	**TAKASHIMA Kazuki**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H28/A10	Development of a sound source segregation system based on artificial intelligence technology	**OZAWA Kenji** Interdisciplinary Graduate School, University of Yamanashi	**SUZUKI Yôiti**
H28/A11	Communication system for controlling human cognition and behavior from kansei information of speech	**TANAKA Akihiro** Department of Psychology, Tokyo Woman's Christian University	**SAKAMOTO Shuichi**
H28/A13	Study of the cooperative environment system for building visual cognition models.	**SAKAI Ko** Faculty of Engineering Information and Systems, Tsukbua University	**SHIOIRI Satoshi**
H28/A14	International deployment of wide area distributed platform with autonomous validation of disaster and fault tolerance	**KASHIWAZAKI Hiroki** Cybermedia Center, Osaka University	**MURAOKA Hiroaki**
H28/A15	Japan-USA International Collaborative Research on Graphene-Based Atomically-Thin 2D Heterostructures and their Terahertz Applications	**MITIN, Vladimir** Department of Electrical Engineering, University at Buffalo, State University of New York	**OTSUJI Taichi**
H28/A16	Electrical manipulation of magnetization and spin dynamics through spin-orbit interaction	**KOHDA Makoto** Graduate School of Engineering, Tohoku university	**KANAI Shun**
H28/A17	Inducing techniques for magnetic anisotropy of amorphous magnetostrictive films using inverse-magnetostriction effect and its applications	**HASHI Shuichiro** Research Institute of Electrical Communication, Tohoku University	**HASHI Shuichiro**
H28/A20	Display technology for high dynamic range images using a stochastic dithering method	**NAGAI Takehiro** Graduate School of Science and Engineering, Yamagata University	**KURIKI Ichiro**
H28/A21	Application of 3D Interactive Technologies to Everyday Gesture-based Human-Computer Interaction based on Design Methodology	**KITAMURA Yoshifumi** Research Institute of Electrical Communication, Tohoku University	**KITAMURA Yoshifumi**
H28/A22	Reproduction of ultra-realistic space using ultra-high definition Omni-direction image and sound	**OKUDO Masami** Faculty of Tourism, Wakayama University	**SUZUKI Yôiti**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H28/A23	Detection and Prediction of Abnormal State from Multivariate Bio-signals	**CHAKRABORTY Goutam** Department of Software and Information Science, Iwate Prefectural University	**KINOSHITA Tetsuo**
H28/A24	Intelligent Network Security Technologies for Next-Generation IoT Platform	**NAGAYAMA Shinobu** Graduate School of Information Sciences, Hiroshima City University	**NATSUI Masanori**
H29/A01	Studies on fabrication of ferromagnet/semiconductor hybrid structures and their application for spintronics devices	**MATSUKURA Fumihiro** Advanced Institute Materials Research, Tohoku University	**SHIRAI Masafumi**
H29/A02	Development of low-loss flexible metamaterials	**UCHINO Takashi** Department of Electronics and Intelligent Systems, Faculty of Engineering, Tohoku Institute of Technology	**OTSUJI Taiichi**
H29/A03	Evaluation of layered structure in dielectric devises using scanning nonlinear dielectric microscopy	**ODAGAWA Hiroyuki** Innovative Research Center, National Institute of Technology, Kumamoto College	**CHO Yasuo**
H29/A04	Ultra-High Sensitive Nuclear-Spin Investigation of Nano-Scale Properties in Spintronics Materials	**SASAKI Susumu** Faculty of Engineering, Niigata University	**FUKAMI Shunsuke**
H29/A05	Fabrication of high-performance and integrated-optoelectrical device with atomically thin layered materials	**KATO Toshiaki** Graduate School of Engineering, Tohoku University	**YAMASUE Kohei**
H29/A06	Development of innovative optical measurement and quantum information and communication technology by using superconducting photon detector array	**TERAI Hirotaka** Advanced ICT Research Institute, National Institute of Information and Communications Technology	**EDAMATSU Keiichi**
H29/A07	Research on device application of single-crystal graphene	**NAGASE Masao** Graduate School of Science and Technology, Tokushima University	**OTSUJI Taiichi**
H29/A08	Atomic Control in New Group-IV Semiconductor Nanostructures for High-Performance Device	**SAKURABA Masao** Research Institute of Electrical Communication, Tohoku University	**SAKURABA Masao**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H29/A09	Study of the effect of post-deposition processing on various type high-k/Ge structure	**OKAMOTO Hiroshi** Graduate School of Science and Technology, Hirosaki University	**SATO Shigeo**
H29/A10	Development of graphene based devices for terahertz applications	**MEZIANI, Yahya Moubarak** Fisica Aplicada, Salamanca University	**OTSUJI Taichi**
H29/A11	Theoretical Study of Nonequilibrium Dynamics of Electrons and Plasmons in Two-Dimensional Electron Systems	**SVINTSOV, Dmitry** Laboratory of 2d Materials' Optoelectronics, Moscow Institute of Physics and Technology	**SATOU Akira**
H29/A12	Massive Connect IoT Using a Precision Position and Time Information on QZSS	**OGUMA Hiroshi** Department of Electronics and Computer Engineering, National Institute of Technology, Toyama College	**KAMEDA Suguru**
H29/A13	Studies on direct digital RF transceivers	**SUEMATSU Noriharu** Research Institute of Electrical Communication, Tohoku University	**SUEMATSU Noriharu**
H29/A14	Using Deep Learning for Human Motion Analysis and Synthesis, and Its Application to HCI	**KOMURA Taku** School of Informatics, Edinburgh University	**KITAMURA Yoshifumi**
H29/A15	Evaluation of Multimedia Contents based on EEG Activities of Multiple Subjects	**TOUYAMA Hideaki** Faculty of Engineering, Toyama Prefectural University	**KITAMURA Yoshifumi**
H29/A16	Cultural and individual differences in color lexicon	**TOKUNAGA Rumi** College of Liberal Arts and Sciences, Chiba University	**SHIOIRI Satoshi**
H29/A17	Development of Ion channel sensing system with high sensitivity and high accuracy based on silicon microfabrication and lipid bilayers	**TERO Ryugo** Department of Environmental and Life Sciences, Toyohashi University of Technology	**HIRANO Ayumi**
H29/A18	Speech intelligibility evaluation and its estimation for development of outdoor public address system.	**KOBAYASHI Yosuke** Graduate School of Engineering, Muroran Institute of Technology	**SAKAMOTO Shuichi**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H29/A19	Gaze Visualization in Collaboration	KIYOKAWA Kiyoshi Cybermedia Center, Osaka University	KITAMURA Yoshifumi
H29/A20	Development of object based audio with surrounding loudspeaker array system and sound field rendering	TSUCHIYA Takao Faculty of Scince and Engineering, Doshisha University	SAKAMOTO Shuichi
H29/A21	Practical applications of nonlinear and complex systems theory to nonlinear-complex engineering systems	HORIO Yoshihiko Research Institute of Electrical Communication, Tohoku University	HORIO Yoshihiko
H29/A22	Temporal characteristics of multisensory auditory space perception	HONDA AKio Faculty of Human Sciences and Cultural Studies, Yamanashi-Eiwa College	SAKAMOTO Shuichi
H29/A23	Immersive experience of virtual auditory environment: investigating influence of physical parameters of height ambiences	KIM, Sungyoung Electrical, Computer and Telecommunications Engineering Technology, Rochester Institute of Technology	SAKAMOTO Shuichi
H29/A24	Mind and environment interface: Human attention in the brain	LI, Jing-Ling Laboratory of visual attention, Graduate Institute of Biomedical Sciences, China Medical University	TSENG Chia-Huei
H29/A25	The effect of attention on the integration of image components in the human visual system	CHEN, Chien-Chung Psychology/Visual Neuroscience Lab, National Taiwan University	TSENG Chia-Huei
H29/A26	Social communication: behavioral and brain representations	TSENG, Chia-Huei Research Institute of Electrical Communication, Tohoku University	TSENG Chia-Huei
H29/A27	Next Generation Information Flow Processing Platform for Human-in-the-loop IoT	YAMAGUCHI Hirozumi Graduate School of Information Science and Technology, Osaka University	KITAGATA Gen
H29/A28	On the relationship between three-dimensional shape of pinna and direction selectivity of acoustic transfer function	ITO Masashi Faculty of Engineering, Tohoku Institute of Technology	SAKAMOTO Shuichi

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H29/A29	Research on the development of a new generation IoT platform	**ZABIR Salahuddin Muhammad Salim** Department of Creative Engineering, National Institute of Technology, Tsuruka College	**KINOSHITA Tetsuo**
H29/A30	Study on Social Networking Service Deployed in Real World	**YAMAZAKI Tatsuya** Graduate School of Science and Technology, Niigata University	**TAKAHASHI Hideyuki**
H29/A31	Study on low hysteresis and continuous magnetoimpedance sensor applied for strong magnetic field	**NAKAI Tomoo** Erectronics and information technology department, Industrial Technology Institute, Miyagi Prefectural Government	**ISHIYAMA Kazushi**
H29/A32	Formation of MEMS with BiFeO3 thin films and wireless communication technology	**IMAIZUMI Fuminobu** Department of Mechanical Engineering, National Institute of Technology, Oyama College	**KAMEDA Suguru**
H29/A33	Development study on high sensitive gas sensors with titania nanotubes	**NIWANO Michio** Kansei Fukushi Research Institute, Tohoku Fukushi University	**HIRANO Ayumi**
H29/A34	Analyzing the relationship between network structure and function in cortex	**KUBOTA Shigeru** Graduate School of Science and Engineering, Yamagata University	**HIRANO Ayumi**
H29/A35	Understanding and reconstruction of minimal brain	**KAMIYA Haruyuki** Graduate School of Medicine, Hokkaido University	**HIRANO Ayumi**
H29/A36	Creative Application of 3D Magnetic Motion Tracking System to Music: the CubeHarmonic	**KITAMURA Yoshifumi** Research Institute of Electrical Communication, Tohoku University	**KITAMURA Yoshifumi**
H27/B01	Finding innovative reactive fields related with multi-scale structures in various plasma flows	**ANDO Akira** Graduate School of Engineering, Tohoku University	**SUEMITSU Maki**
H27/B03	Physics of quantum measurement and communication	**EDAMATSU Keiichi** Research Institute of Electrical Communication, Tohoku University	**EDAMATSU Keiichi**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H27/B04	Physics and application of spin dynamics in solids	**MATSUKURA Fumihiro** Advanced Institute Materials Research, Tohoku University	**KANAI Shun**
H27/B05	Evaluation of telecommunication handset performance under the influence of broadband unnecessary radio wave	**YAMAGUCHI Masahiro** Graduate School of Engineering, Tohoku University	**ISHIYAMA Kazushi**
H27/B06	Methodology of Science and the Implementation for Education Based on the Harmony between Subjectivity and Humanity - For the Issues of Modern Science and Future Mankind -	**TSUDA Ichiro** Academy of Emerging Sciences, Chubu University	**OHORI Atsushi**
H27/B07	Parallel processes of brain functions	**TSUTSUI Ken-Ichiro** Graduate School of Life Sciences, Tohoku University	**SHIOIRI Satoshi**
H27/B08	Optimization of Information Representation on a High-Dimensional Neural Network	**HIROSE Akira** Graduate School of Engineering, Tokyo University	**SATO Shigeo**
H27/B09	Functionalization of oxide surfaces and its application to nanodevices	**HIROSE Fumihiko** Graduate School of Science and Engineering, Yamagata University	**HIRANO Ayumi**
H27/B13	Studies on enrichment of media technologies	**AOKI Naofumi** Graduate School of Information Science and Technology, Hokkaido University	**SUZUKI Yôiti**
H28/B01	Precise Solid State Science and its Device Applications via Controlling Charge and Spin of Electrons	**KOBAYASHI Kensuke** Graduate School of Science, Osaka University	**FUKAMI Shunsuke**
H28/B03	Various media of particle-fluid hybrid system with charging effects and their potential functions	**SAKAI Osamu** Department of Electronic Systems Engineering, The University of Shiga Prefecture	**SATO Shigeo**
H28/B04	Visual mechanisms for SHITSUKAN perception.	**OKAJIMA Katsunori** Faculty of Environment and Information Sciences, Yokohama National University	**KURIKI Ichiro**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H28/B05	A Study for Human, Space, and Information Technologies	KITAMURA Yoshifumi Research Institute of Electrical Communication, Tohoku University	KITAMURA Yoshifumi
H28/B06	Logical Approach to Formalization of Mathematics	SAKURAI Takafumi Graduate School of Science, Chiba University	TOYAMA Yoshihito
H28/B07	Technical fusion of industrial programming language development and academic research on programming languages	MATSUMOTO Yukihiro Board, Ruby Association	UENO Katsuhiro
H28/B08	Application study of Microwave and Laser Aided Synthetic Aperture Radar	KOGI Yuichiro Department of Engineering, Fukuoka Institute of Technology	YASAKA Hiroshi
H28/B09	Constructing next-generation academic community that applies human-computer interaction researches	SAKAMOTO Daisuke Graduate School of Information Science and Technology, Hokkaido University	KITAMURA Yoshifumi
H28/B10	Magnetic Field Measurement System using Magneto-optical Effect	ISHIYAMA Kazushi Research Institute of Electrical Communication, Tohoku University	ISHIYAMA Kazushi
H28/B11	Development of HCI Research Activities in Asia	KITAMURA Yoshifumi Research Institute of Electrical Communication, Tohoku University	KITAMURA Yoshifumi
H28/B12	Study on mechanisms of visual processing with eye movements	MATSUMIYA Kazumichi Research Institute of Electrical Communication, Tohoku University	MATSUMIYA Kazumichi
H28/B13	Novel device applying chemical sensors for multi-parameter measurement	MIYAMOTO Ko-ichiro Graduate School of Engineering, Tohoku University	HIRANO Ayumi
H28/B14	Research on information quality and value	MURAOKA Hiroaki Research Institute of Electrical Communication, Tohoku University	MURAOKA Hiroaki

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H28/B15	Research and development of multi purpose micro gimbal and its applications	**SUEDA Koh** Interactive Digital Media institute, National University of Singapore	**KITAMURA Yoshifumi**
H29/B01	Study of functional piezoelectric materials and applications to advanced communication devices	**UMEMURA Shin-ichiro** Graduate School of Biomedical Engineering, Tohoku University	**SUZUKI Yôiti**
H29/B02	Research on magnetic device for advanced communications equipment by observation and control of microstructure of magnetic material	**IKEDA Shinji** Department of Electrical and Control Systems Engineering, National Institute of Technology, Toyama College	**ISHIYAMA Kazushi**
H29/B03	Study on semiconductor device and its integrated electronics systems for high efficiency energy utilization	**CHIKYOW Toyohiro** International Center for Materials Nanoatrchectonics MANA, National Institute for Materials Science	**OHNO Hideo**
H29/B04	Development of nano-scale structural design method from first-principles calculation	**GESHI Masaaki** Institute for NanoScience Design, Osaka University	**ABE Kazutaka**
H29/B05	Research on new concept devices with nano materials / silicon integrated circuit hybrid technology and its application for information processing	**WATANABE Heiji** Graduate School of Engineering, Osaka University	**OHNO Hideo**
H29/B06	Smart Spectrum and Its Applications for IoT Era	**FUJII Takeo** Advanced Wireless and Communication Research Center, The University of Electro-Communications	**KAMEDA Suguru**
H29/B07	Advanced high-frequency circuit technology for realizing wireless IoT and its application	**ITOH Nobuyuki** Faculty of Computer Science and Systems Engineering, Okayama Prefectural University	**SUEMATSU Noriharu**
H29/B08	Full-Coherent Communication and Measurement Systems Aiming at Seamless Interface Between Light- and Micro-Waves	**TSUCHIDA Hidemi** Electronics and Photonics Research Institute, National Institute of Advanced Industrial Science and Technology	**NAKAZAWA Masataka**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H29/B09	Spatial User Interface by Understanding Human's Physical and Spatial Behaviors	**YAMAMOTO Goshiro** Kyoto University Hospital, Kyoto University	**TAKASHIMA Kazuki**
H29/B10	New Horizon: Research on Interactive Content Design	**KITAMURA Yoshifumi** Research Institute of Electrical Communication, Tohoku University	**KITAMURA Yoshifumi**
H29/B11	Multisensory integration including self-motion perception	**SAKURAI Kenzo** Faculty of Liberal Arts, Tohoku Gakuin University	**SUZUKI Yôiti**
H29/B12	Search Science: an interdisciplinary endeavor	**TSENG, Chia-Huei** Research Institute of Electrical Communication, Tohoku University	**TSENG Chia-Huei**
H29/B13	Research on Declarative High Performance Computing Framework and Its Applicaion	**OHORI Atsushi** Research Institute of Electrical Communication, Tohoku University	**OHORI Atsushi**
H29/B14	Kotology: What is the minimum set for creating diverse actions of living things	**OSUKA Koichi** Graduate School of Engineering, Osaka University	**ISHIGURO Akio**
H29/B15	Neuromorphic computing utilizing novel solid-state devices and circuits	**FUKAMI Shunsuke** Research Institute of Electrical Communication, Tohoku University	**FUKAMI Shunsuke**
H29/B16	Study on the analysis of electromagnetic waves in security hardware	**NAGATA Makoto** Graduate School of Science Technology and Innovation, Kobe University	**HOMMA Naofumi**
H29/B17	International Research Collaboration of Brainware LSI and Its Applications	**HANYU Takahiro** Research Institute of Electrical Communication, Tohoku University	**HANYU Takahiro**
H29/B18	Advanced Hardware Security Technology	**HOMMA Naofumi** Research Institute of Electrical Communication, Tohoku University	**HOMMA Naofumi**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H29/B19	Electromagnetic Information Security	**HAYASHI Yuichi** Graduate School of Information Science, Nara Institute of Science and Technology	**HOMMA Naofumi**
H29/B20	New developments and applications of semiconductor technologies based on university-induys	**SUEMITSU Maki** Research Institute of Electrical Communication, Tohoku University	**SUEMITSU Maki**
H29/B21	Development of wide area vocal system for crows' behavior control	**TSUKAHARA Naoki** The Center for the Promotion of Integrated Sciences, The Graduate University for Advanced Studies	**KITAMURA Yoshifumi**
H29/B22	Research/survey of enhancing UI/UX for drone use of entertainment at EC2017	**SUEDA Koh** Interactive Digital Media institute, National University of Singapore	**KITAMURA Yoshifumi**
H29/B23	Asynchronous Stochastic Computation for Brainware System	**ONIZAWA Naoya** Frontier Research Institute for Interdisciplinary Sciences, Tohoku University	**HANYU Takahiro**
H27/S1	Empathic Computing System through interactive knowledge emergence based on massive data processing	**KOMATANI Kazunori** The Institute of Scientific and Industrial Research,, Osaka University	**KITAMURA Yoshifumi**
H29/S1	Project for creation of interdisciplinary, advanced science and technology based oncoherent wave	**MIMURA Hidenori** Research Institute of Electronics,, Shizuoka University	**YASAKA Hiroshi**
H29/S2	Collaborative Research on Nano-electronics	**UDAKA Katsuyuki** Research Organization for Nano & Life Innovation,, Waseda University	**SUEMITSU Maki**
H29/S3	Innovation of Electrical Communication Systems based on Design	**SAWARAGI Tetsuo** Collaborative Graduate Program in Design, Kyoto University	**KITAMURA Yoshifumi**

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
81	RIEC Russia-Japan Joint International Microwave Workshop 2017	Oct.19-20,2017

	Title	Date
82	International Symposium on Photonics and Optical Communications (ISPOC 2017)	Oct.25-26,2017
83	RIEC International Symposium on Experience Design and Cognitive Science (The Second ACM SIGCHI Asian Symposium)	Nov. 18-19,2017
84	15th RIEC International Workshop on Spintronics	Dec.13-14,2017
85	The 6th RIEC International Symposium on Brain Functions and Brain Computer	Feb. 1-2,2018
86	The 5th International Symposium on Brainware LSI	Feb. 23-24,2018
87	The 9th International Workshop on Nanostructures and Nanoelectronics	Mar. 1-2,2018

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. Qiang Chen
Manager	Assistant Prof. Keisuke Konno

Acoustic Engineering	
Chair	Prof. Yôiti Suzuki
Manager	Associate Prof. Shuichi Sakamoto
Manager	Associate Prof. 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. Ayumi Hirano
Manager	Associate Prof. Koichiro Miyamoto

Spinics	
Chair	Prof. Kenji Nakamura
Manager	Associate Prof. Yasushi Endo
Manager	Assistant Prof. Yoshiaki Hayashi

New Paradigm Computing	
Chair	Prof. Masanori Hariyama
Manager	Associate Prof. Masanori Natsui

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	Associate Prof. Masayuki Ohzeki
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	Associate Prof. Syunsuke Fukami

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)
- IHP-Innovations for High Performance Microelectronics (Germany)
- The 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)
- Telecom Paris Tech (France)
- University of Calfornia, Santa Barbara (U.S.A.)
- Purdue University(U.S.A.)
- The University of York (U.K.)
- The Technische Universität Dresden(Germany)
- Berlin Institute of Technology(Germany)
- National Tsing Hua University(Taiwan)
- Harvard University (U.S.A.)
- The University of Kaiserslautern (Germany)
- Johannes Gutenberg University (Germany)
- University of Regensburg (Germany)
- Carl von Ossietzky University of Oldenburg (Germany)

(＊: expired program)

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

1	Acoustical Science & Technology
2	Applied Acoustics
3	Electronic Journal of Surface Science and Nanotechnology
4	IACR Transactions on Cryptographic Hardware and Embedded Systems
5	IEEE Virtual Reality Journal Track (IEEE Transactions on Visualizaton and Computer Graphics)
6	IEICE Transactions on Communications (EB)
7	International Journal of Energy, Information and Communications
8	Journal of Cryptographic Engineering
9	Journal of informatin hiding and multimedia signal processing
10	Mobile Information Systems
11	Neural Networks
12	Nonlinear Theory and Its Applications, IEICE
13	Scientific Reports (Nature Publishing Group)
14	Soft Robotics

Recent international conferences programmed by a staff in RIEC

1	12th Global Symposium on Millimeter Waves (GSMM) 2019
2	12th Japan-Korea Conference on Ferroelectrics
3	15th RIEC International Workshop on Spintronics
4	2017 Asian Pacific Conference on Vision
5	2018 ISAF-FMA-AMF-AMEC-PFM Joint Conference (IFAAP 2018)
6	5th ACM International Conference on Nanoscale Computing and Communication (ACS-NanoComm)
7	9th International Workshop on Nanostructures & Nanoelectronics
8	ACM Conference on Interactive Surfaces and Spaces 2017
9	ACM SIGGRAPH Conference and Exhibition on Computer Graphics and Interactive Techniques in Asia 2017
10	ACM Symposium on Spatial User Interface 2017
11	ACM Symposium on Virtual Reality Software and Technology (VRST) 2017
12	ACSIN14 & ICSPM26
13	Asia-Pacific Microwave Conference 2018
14	Asia-Pacific Workshop on Fundamentals and Applications of Advanced Semiconductor Devices(AWAD)
15	European Material Research Society Fall Meeting 2018 (MRS-E Fall Meeting)
16	European Microwave Week 2018
17	IEEE International Sympoisum on Asynchronous Circuits and Systems 2019
18	IEEE International Symposium on Multiple-Valued Logic 2017
19	Int. Conf. on Micro- and Nano-Electronics (ICMNE)
20	International Conference on Artificial Reality and Telexistence & Eurographics Symposium on Virtual Environments (ICAT-EGVE) 2017
21	International Conference on Cryptographic Hardware and Embedded Systems 2017
22	International Conference on InfraRed, MilliMeter Wave and TeraHerz (IRMMW-THz 2018)

23	International Conference on Recent Progress in Graphene Research (RPGR)
24	International Conferences on Modern Materials & Technologies (CIMTEC)
25	International Symposium on Compound Semiconductors (ISCS)
26	Korea-Japan Microwave Workshop (KJMW2017)
27	Optical Nanofibre Applications: From Quantum to Bio Technologies
28	RIEC International Symposium on Photonics and Optical Communications (ISPOC2017)
29	RIEC Russia-Japan Joint International Microwave Workshop 2017
30	Russia-Japan-USA-Europe Symposium on Fundamental & Applied Problems of Terahertz Devices & Technologies 2018 (RJUSE 2018)
31	Technical Committee of Multiple-Valued Logic, IEEE Computer Society 2017
32	The 2018 International Workshop on Pervasive Flow of Things (PerFoT)
33	The 31st IEEE International Conference on Advanced Information Networking and Applications (AINA-2017)
34	The 3rd International Symposium on Intelligent Systems Technologies and Applications (ISTA'17)
35	The 5th International Symposium on Brainware LSI
36	The 6th IEEE Global Conference on Consumer Electronics 2017 (GCCE2017)
37	The 6th International Conference on Emerging Internet, Data & Web Technologies (EIDWT-2018)
38	The 6th RIEC International Symposium on Brain Functions and Brain Computer
39	The 8th International Symposium on Adaptive Motion of Animals and Machines (AMAM2017)
40	The 9th Asian Conference on Intelligent Information and Database Systems (ACIIDS 2017)
41	The International Multisensory Research Forum 2017 (IMRF2017)
42	The Twelfth International Conference on Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP2017)
43	Tohoku-Purdue Workshop on Novel Spintronics Physics and Materials for Future Information Processing
44	Tohoku-York-Kaiserslautern 6th Core-to-core Workshop on "New-Concept Spintronics Devices"
45	Topical Workshop on Heterostructure Microelectronics (TWHM)
46	VLSI Circuits Symposium 2017

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 was also launched 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, 2017

Professors	24
Associate Professors	22
Assistant Professors	18
Research Fellows	5
Specially Appointed Professors	1
Specially Appointed Assistant Professors	2
Administrative Staff	14
Technical Staff	13
Total	99

2. Researchers (FY2017)

Foreign Researchers	Visiting Professors	7
	Visiting Asociate Professors	5
Cooperative Researchers of Private Company etc		7
JSPS Research Fellowship for Young Scientists		9
JSPS Postdoctral Fellowship for Overseas Researchers		2
Invitation Fellowship for Research in Japan		1
Contract Researchers		3
Contract Trainees		1
Total		35

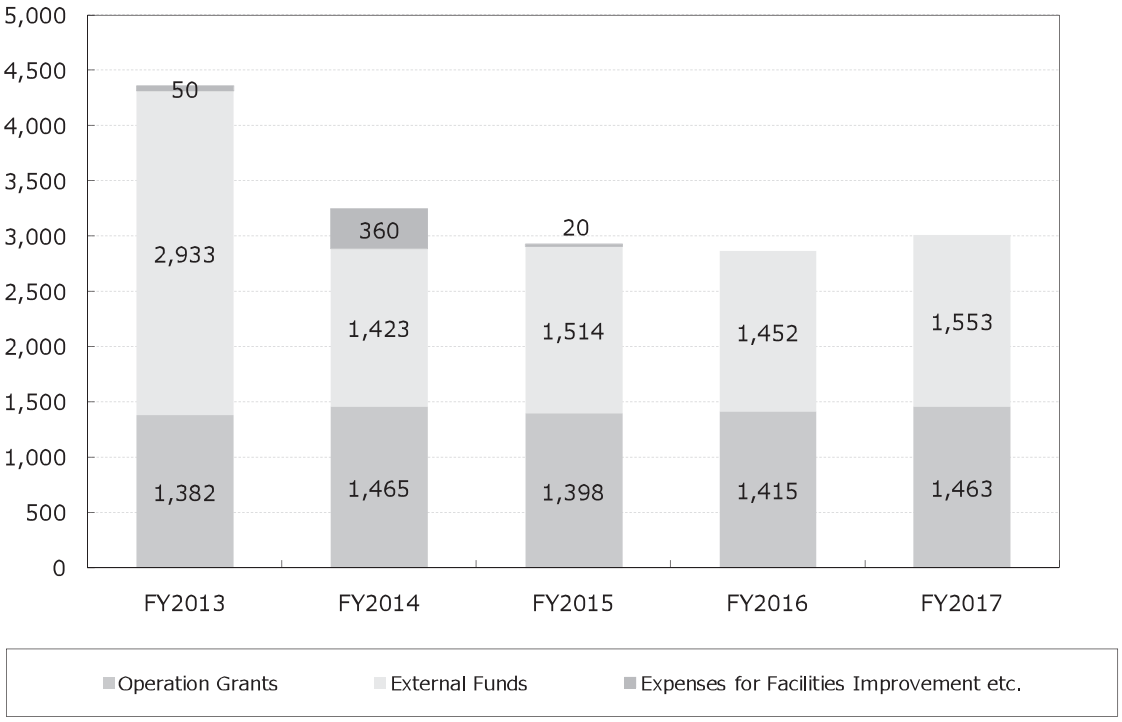
3. Students

as of May 1, 2017

	School of Engineering	Graduate School of Information Science	Graduate School of Biomedical Engineering	RIEC	Total
Undergraduate Students	57				57
Master Course Students	85 (8)	54 (11)	2		141 (19)
Doctor Course Students	25 (8)	14 (7)			39 (15)
Institute Reserch Students				1 (1)	1 (1)
Total	167 (16)	68 (18)	2	1 (1)	238 (35)

4. Budget

Budget Shift



■ Budget Summary

thousand yen

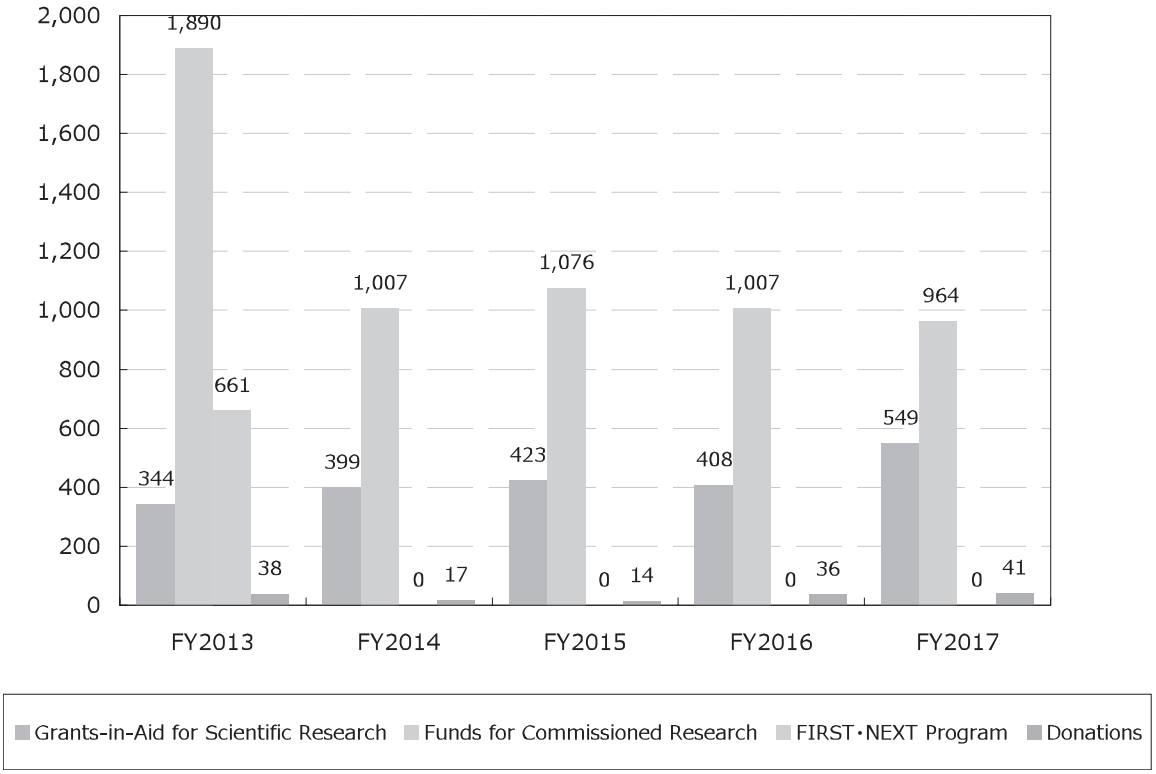
Categories		FY2013	FY2014	FY2015	FY2016	FY2017
Operation Grants	Personnel Expenses	723,507	795,601	730,537	808,066	835,904
	Non-Personnel Expenses	658,590	668,941	667,582	606,599	626,824
Operation Grants Total		1,382,097	1,464,542	1,398,119	1,414,665	1,462,728
External Funds	Grants-in-Aid for Scientific Research	343,824	399,311	422,846	407,902	549,034
	Funds for Commissioned Research	1,890,012	1,007,060	1,076,220	1,007,451	963,585
	FIRST Program※1・NEXT Program※2	660,578	0	0	0	0
	Donations	38,100	16,890	14,490	36,190	40,541
	Indirect Expenses	336,037	212,669	219,886	244,413	220,733
External Funds Total		2,932,514	1,423,261	1,513,556	1,451,543	1,553,160
Expenses for Reconstruction		0	0	0	0	0
Expenses for Relocation		49,632	359,770	20,011	0	0
Expenses for Facilities Improvement		0	0	0	0	0
Expenses for Facilities Improvement etc. Total		49,632	359,770	20,011	0	0
Total		4,364,243	3,247,573	2,931,686	2,866,208	3,015,888

※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

million yen



■ External Funds

thousand yen

Categories	FY2013	FY2014	FY2015	FY2016	FY2017
Grants-in-Aid for Scientific Research	343,824	399,311	422,846	407,902	549,034
Funds for Commissioned Research	1,890,012	1,007,060	1,076,220	1,007,451	963,585
FIRST Program※1・NEXT Program※2	660,578	0	0	0	0
Donations	38,100	16,890	14,490	36,190	40,541
Total	2,932,514	1,423,261	1,513,556	1,451,543	1,553,160

※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 2017

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