Annual Report 2018

Research Institute of Electrical Communication
Tohoku University

Annual report of Research Institute of Electrical Communication 2018

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 Japan's Fifth Science and Technology Basic Plan 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, universities are expected to conduct basic researches, some of which would create innovations that enriches the society. We have such examples in the history of our institute, such as Professor Junichi Nishizawa's three elements of optical communication and Professor Shunichi Iwasaki's perpendicular magnetic recording. They started related basic researches at RIEC, which opened new fields in ICT eventually. A more recent case is spintronics, which Professor Hideo Ohno has led from basic science to application to new devices. Magnetoresistive Random Access Memory (MRAM) is a device that uses the spintronics technology, and is attracting public attention as the promising candidate of a critical and emerging device in the near future ICT. The environment in which Tohoku University and RIEC operate is constantly changing. Recognizing roles of university, RIEC must utilize resources efficiently to execute its mission and develop the environment for the purpose.

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 fourth 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

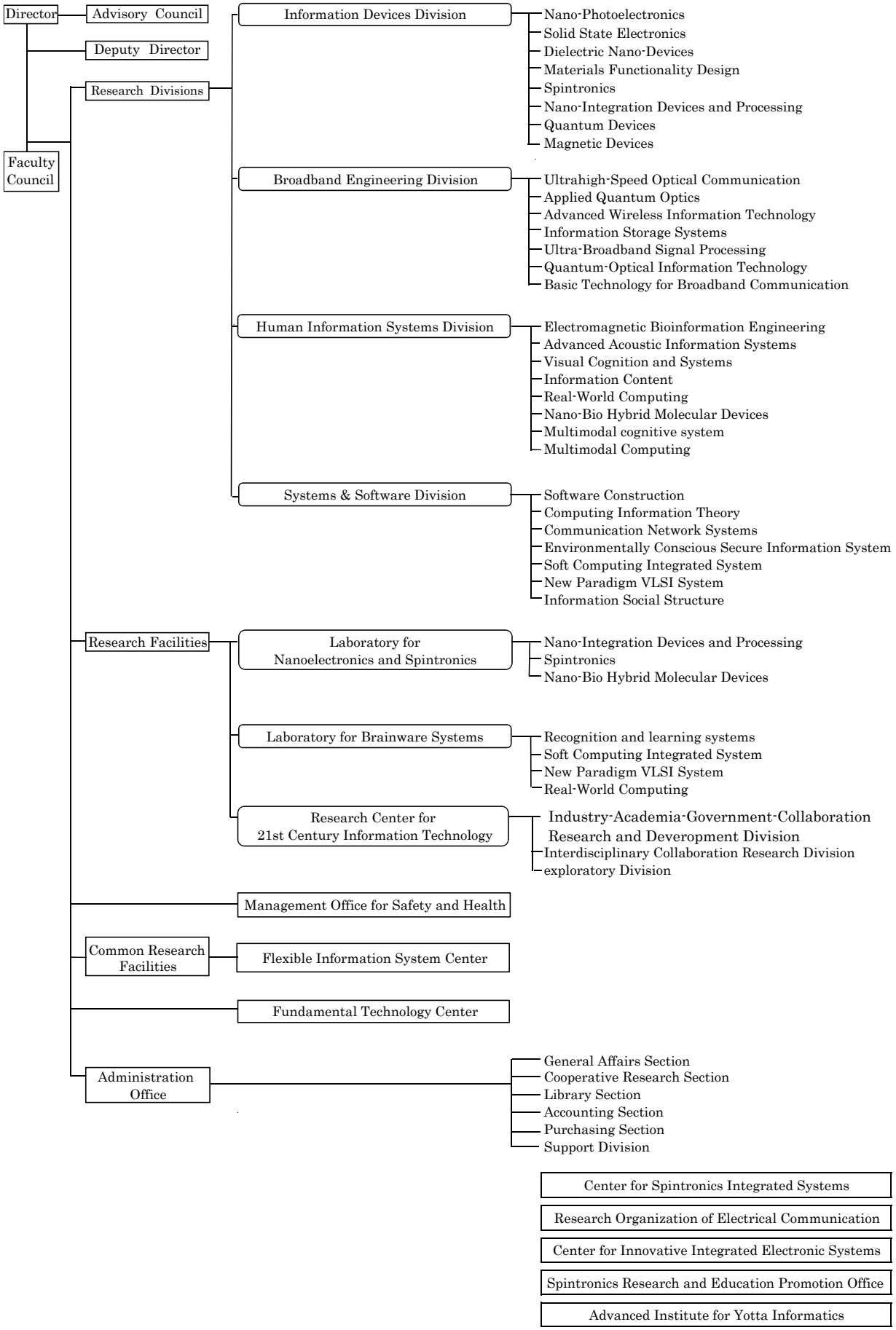
laboratories, collaborative research projects, international activities, social contributions, the RIEC symposia, activities of the engineering research association, and RIEC lectures. The bibliography section also includes data on the various activities we have conducted over the last five years.

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

May 31, 2019

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 advanced nano-information devices utilizing physical phenomena. To accomplish this goal, we conduct research on subjects related to material design, evaluation, process, device, and system. The research developed in this division provides an important basis for achieving the purpose of foundation of this research institute, and we aim to develop completely new functional information devices for next-generation information processing and communication. Thus we study new functionalities employing exotic materials and nanostructures, and apply such functionalities to nanophotoelectronic devices, new dielectrics-based nano-devices for information storage, quantum electronics devices, spintronics devices, and next generation semiconductor devices.

To achieve the goal, the following 8 laboratories are carrying out researches and developments.

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 2018 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 2018 is as follows. (1) We have been developing time resolved STM light emission spectroscopy, which has ps temporal resolution in addition to atomic spatial and meV energy resolutions. This method was applied to Ni(110)-ST(2×1) H in this year. Since the adsorption site of the H atoms in this system is unique, three vibrational energies should be observed in the STM light spectra. In fact, the vibrational mode with the highest energy is firstly observed in the time resolved STM light emission spectra. Then the remaining two modes appear in a few ps, showing that temporal behaviors of the vibrational modes can be determined. (2) We have developing a vibrational spectroscopic method based on STM light emission spectroscopy. This method was applied to Ni(110)-(2 × 1) O in this year. One can find two kinds of nanometer scale domains in the STM images, but one cannot know the domains on which the oxygen atoms adsorb from the STM images. We successfully determined the oxygen-atom-adsorbed domain from the STM light emission spectra. (3) We have investigated the nanoscale luminescence of the graphene oxide (GO) using STM-LE. We found that GO exhibits strong PL by annealing to 400 ^{o}C. Raman spectroscopy indicated that highly luminescent sp^2 domains were formed via the thermal reduction. STM-LE mapping identified the luminescent sites of GO, which are localized in a few nm regions. (4) LSP-coupled vibrational excitations of the polymer molecule (PVP) adsorbed on silver nanocubes (AgNC) were investigated using STM and Raman spectroscopy. The assembly structures of AgNCs were characterized using AFM and STM, which revealed that the close-packed structure of AgNCs with the face-to-face alignment is achieved by the LB method. The vibrational peaks originated from PVP are clearly seen in the Raman spectra owing to the surface-enhanced Raman scattering effect at the well-ordered two-dimensional arrays of AgNC.

[Staff]

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

[Profile]

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

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

[Papers]

1. Y. Uehara, M. Kuwahara, S. Katano, T. Tanno, and J. Sakai, "Pump–probe scanning-tunneling-microscope light-emission spectroscopy of Sb_2Te_3", J. Appl. Phys., **124**, 075104_1-7 (2018).
2. Y. Uehara, T. Inaoka, T. Nishio, and S. Katano, "Vibration-induced Structures in Scanning Tunneling Microscope Light Emission Spectra of Ni(110)-(2 × 1) O", J. Appl. Phys., **123**, 224302_1-8 (2018).
3. S. Katano, T. Wei, T. Sasajima, R. Kasama, and Y. Uehara, "Localized electronic structures of graphene oxide studied using scanning tunneling microscopy and spectroscopy", Phys. Chem. Chem. Phys., **20**, 17977-17982 (2018).

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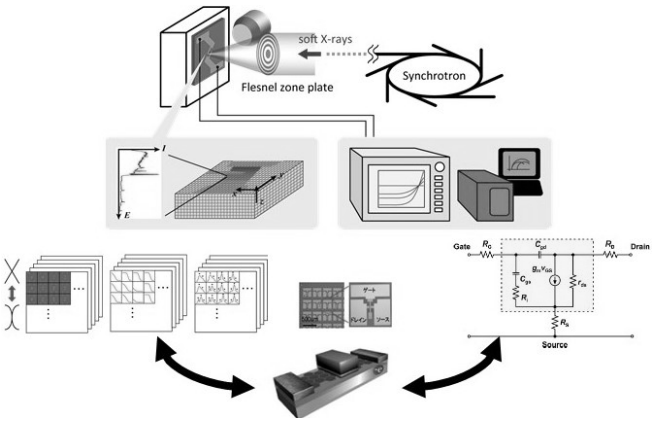
Solid State Electronics Laboratory

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

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 FY2018, we succeeded in raising up high-frequenecy graphene transistor by tuning graphene/dielectric interface and quantitatively evaluating a spatial distribution of surface electron trapping of GaN-HEMT, which causes operation instabilities, so-called current collapse phenomena. Furthermore, we developed spatiotemporal operando x-ray spectroscopy, enabling spatio-temporally examining electronic states of advanced devices.

[Staff]

Associate Professor : Hirokazu Fukidome, Dr.
Research Assistant : Fuminori Sasaki, Mr.
Research Assistant : Kwan-Soo Kim, Dr.
Technical Assistant : Kumi Namiiri
Technical Assistant : Misako Suzuki

[Profile]

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] K.-S. Kim, G.-H. Park, H. Fukidome, T. Someya, T. Iimori, F. Komori, I. Matsuda, and M. Suemitsu, "A table-top formation of bilayer quasi-free-standing epitaxialgraphene on SiC(0001) by microwave annealing in air" Carbon, 130. (2018), pp. 792-798.

[2] T. Someya, H. Fukidome, N. Endo, K. Takahashi, S. Yamamoto, and I. Matsuda, "Interfacial carrier dynamics of graphene on SiC, traced by the full-range time-resolved core-level photoemission spectroscopy", Applied Physics Letters, 113 (2018), pp. 051601-1-051601-4.

[3] K. Omika, Y. Tateno, T. Kouchi, T. Komatani, S. Yaegassi, K. Yui, K. Nakata, N. Nagamura, M. Kotsugi, K. Horiba, M. Oshima, M. Suemitsu, and H. Fukidome, "Operation Mechanism of GaN-based Transistors Elucidated by Element-Specific X-ray Nanospectroscopy", Scientific Reports, 8 (2018), 13268.

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. In addition, SNDM can be used for the evaluation of various semiconductor materials and devices.

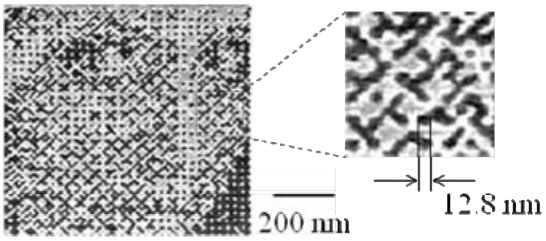


Fig.1 Digital bit data written on ferroelectric single crystal with the areal recording density of 4 Tbit/inch^2.

Major achievements of studies in 2018 are as follows: (1) Local deep level transient spectroscopy (DLTS) based on SNDM has been significantly improved, which allows higher resolution, broader bandwidth, and faster acquisition speed in the nanoscale measurement of interface state density in semiconductor materials and devices (2) We showed SNDM operated in an intermittent contact mode is useful for the nanoscale investigation of carrier concentration distribution in atomically-thin layered semiconductors such as MoS_2. (3) We developed a novel recording medium using $Pb(Zr,Ti)O_3$ thin films, which allows higher speed data readout in hard disk type ferroelectric data storage.

[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. Yamagishi and Y. Cho: "Improvement of local deep level transient spectroscopy for microscopic evaluation of SiO_2/4H-SiC interfaces", Materials Science Forum, Vol. 924, pp.289-292, 2018.
[2] K. Yamasue and Y. Cho: "Local carrier distribution imaging on few-layer MoS_2 exfoliated on SiO_2 by scanning nonlinear dielectric microscopy", Appl. Phys. Lett., Vol. 112, No. 24, pp.243102-1-5, 2018.
[3] Y. Cho and S. Hong: "Scanning probe-type data storage beyond hard disk drive and flash memory", MRS Bulletin, Vol. 43, No. 5, pp.365-370, 2018.

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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)

We reveal the origin of voltage controlled magnetic anisotropy (VCMA) at the MgO/Co/Fe and MgO/Pt/Fe interfaces by ab initio calculations and XMCD measurements. The VCMA of Pt atom is attributed to voltage-induced electric quadrupole as well as voltage –induced orbital magnetic moment.

(2) Dense metallic hydrides

New metallic phases of MgH_4, ZrH_4, and ZrH_6 are predicted at high pressures. The phases are expected to have high superconducting transition temperatures; the highest value reaches 150 K in ZrH_6. It is also pointed out that Mg, Sc, and Zr (namely, diagonally adjacent elements) show structural similarities in dense hydride.

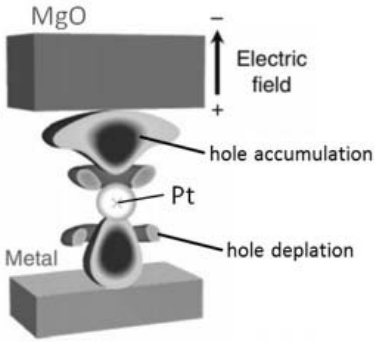


Fig. 1: Voltage-induced charge distribution of Pt atom at the MgO/Pt/Fe interface.

[Staff]

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

[Profile]

Masafumi Shirai received the Doctor of Engineering degree from Osaka University in 1989. Since 2002, he has been a Professor at Tohoku University.
Kazutaka Abe received Doctor of Science degree from Osaka University in 1998. Since 2003, he has been at Tohoku University as a Research Associate, as an Assistant Professor, and currently as an Associate Professor.

[Papers]

[1] K Abe, "High-pressure properties of dense metallic zirconium hydrides studied by ab initio calculations," Phys. Rev. B, Vol. 98, Article No. 134103, pp. 1-7, 2018

[2] S. Miwa, M. Suzuki, M. Tsujikawa, T. Nozaki, T. Nakamura, M. Shirai, S. Yuasa and Y. Suzuki, "Perpendicular magnetic anisotropy and its electric-field-induced change at metal-dielectric interfaces," J. Phys. D: Appl. Phys., Vol. 52, Article no. 063001, pp. 1-22, 2019

[3] Y. Jibiki, M. Goto, M. Tsujikawa, P. Risius, S. Hasebe, X. Xu, K. Nawaoka, T. Ohkubo, K. Hono, M. Shirai, S. Miwa and Y. Suzuki, "Interface resonance in Fe/Pt/MgO multilayer structure with large voltage controlled magnetic anisotropy change," Appl. Phys. Lett., Vol. 114, Article no. 082405, pp. 1-5, 2019

Spintronics

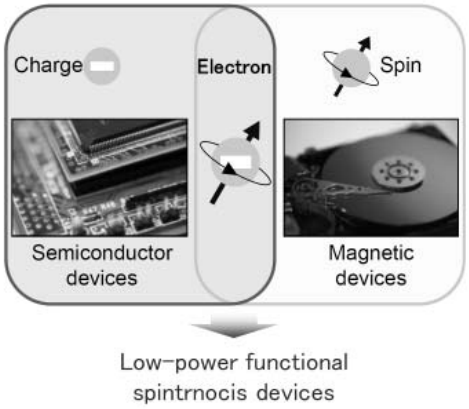
Advanced technology for spintronics-based devices

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) achievement of world's highest spin-orbit torque generation efficiency in high-resistivity-W/CoFeB/MgO heterostructure, (2) world's first observation of magnetoresistance in metallic antiferromagnet/nonmagnet heterostructure, and (3) establishment of high-throughput evaluation scheme of spin-orbit torque switching properties in in-plane magnetized systems.



[Staff]

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

[Profile]

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), Aoba Foundation Award (2017), Asian Union of Magnetics Societies, Young Researchers Award (2018), the Outstanding Research Award of the Magnetics Society of Japan (2018), and Gold Prize of Tanaka Kikinzoku Memorial Foundation (2019).

[Papers]

[1] Y. Takeuchi, C. Zhang, A. Okada, H. Sato, S. Fukami, and H. Ohno, "Spin-orbit torques in high-resistivity-W/CoFeB/MgO," Applied Physics Letters **112**, 192408 (2018).
[2] S. DuttaGupta, R. Itoh, S. Fukami, and H. Ohno, "Angle dependent magnetoresistance in heterostructures with antiferromagnetic and non-magnetic metals," Applied Physics Letters **113**, 202404 (2018).
[3] Y. Takahashi, Y. Takeuchi, C. Zhang, B. Jinnai, S. Fukami, and H. Ohno, "Spin-orbit torque-induced switching of inplane magnetized elliptic nanodot arrays with various easy-axis directions measured by differential planar Hall resistance," Applied Physics Letters **114**, 012410 (2019).

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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.

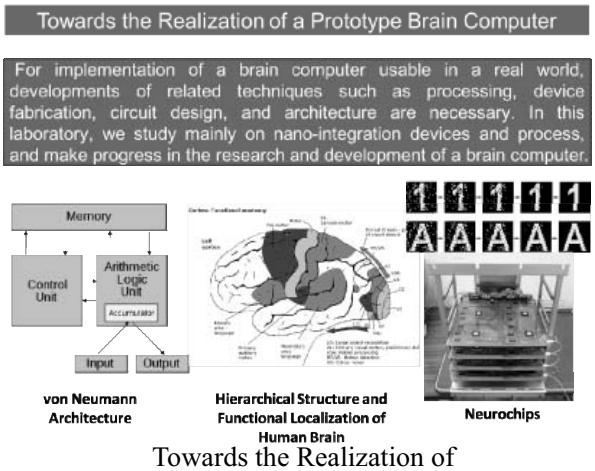
In this year, following experimental results have been obtained: (1) Toward the development of quantum adiabatic computation hardware inspired by brain computation, we studied implementation using superconducting charge qubits. We successfully confirmed by numerical simulations that associative memory function can be obtained by learning. (2) In the depth profiles of P-doped or B-doped Si epitaxial films grown by using low-energy ECR plasma CVD without substrate heating, gradual increasing tendency towards surface was observed. Additionally, improvement for electrical activation of B atoms in the heavily doped film up to above 50% 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.



Towards the Realization of a Prototype Brain Computer

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

[Papers]

[1] S. Moriya, H. Yamamoto, H. Akima, A. Hirano-Iwata, S. Kubota, S. Sato, “Mean-field analysis of directed modular networks,” Chaos, vol. 29, 013142, 2019.
[2] H. Akima, S. Kurihara, S. Moriya, S. Kawakami, J. Madrenas, M. Yano, K. Nakajima, M. Sakuraba, S. Sato, “Motion Stereo Vision LSI for Spatial Perception,” Proc. 2018 Int. Symp. on Nonlinear Theory and Its Applications (NOLTA2018), 663, 2018.
[3] M. Sakuraba and S. Sato, "Epitaxy and In-Situ Doping in Low-Energy Plasma CVD Processing for Group-IV Semiconductor Nanoelectronics" (**Invited Lecture**), 11th Int. Symp. on Advanced Plasma Science and its Application for Nitrides and Nanomaterials / 12th Int. Conf. on Plasma-Nano Technology & Science (ISPlasma/IC-PLANTS), Nagoya, Japan, Mar. 17-21, 2019, No.19aC06I.

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 2018 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 and data informatics approaches.

(2) Measurement of local electronic states and their dynamics

We measured real-time changes 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 movement of a single electron [1].

(3) Quantum bit experiments

We applied the local measurement techniques to quantum bit experiments. We realized precise quantum bit operations, conversion between different qubits and multiple quantum dot operations [2, 3].

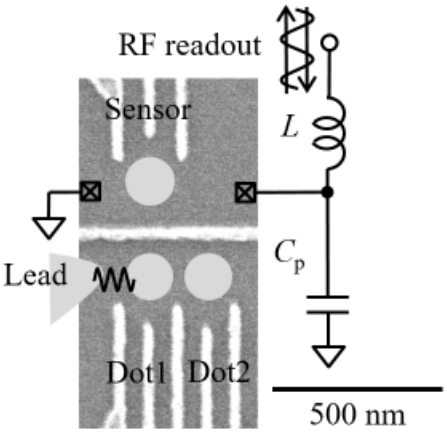


Figure: Scanning electron micrograph of the nanostructure devices

[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), 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. Otsuka, T. Nakajima, M. R. Delbecq, P. Stano, S. Amaha, J. Yoneda, K. Takeda, G. Allison, S. Li, A. Noiri, T. Ito, D. Loss, A. Ludwig, A. D. Wieck, and S. Tarucha, "Difference in charge and spin dynamics in a quantum dot-lead coupled system", Physical Review B 99, 085402 (2019).

[2] A. Noiri, T. Nakajima, J. Yoneda, M. R. Delbecq, P. Stano, T. Otsuka, K. Takeda, S. Amaha, G. Allison, K. Kawasaki, A. Ludwig, A. D. Wieck, and S. Tarucha, "A fast quantum interface between different spin qubit encodings", Nature Communications 9, 5066 (2018).

[3] T. Nakajima, M. R. Delbecq, T. Otsuka, S. Amaha, J. Yoneda, A. Noiri, K. Takeda, G. Allison, A. Ludwig, A. D. Wieck, X. Hu, F. Nori, and S. Tarucha, "Coherent transfer of electron spin correlations assisted by dephasing noise", Nature Communications 9, 2133 (2018).

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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) Ultrahigh-Speed Optical Communication

We are engaged in research on ultrahigh-speed optical transmission, digital coherent transmission, and high-speed and spectrally efficient optical transmission by combining these two approaches. With a view to supporting innovative new ICT services such as 5G and IoT, our goal is also to develop novel transmission schemes integrating optical and wireless communications.

This year, we successfully achieved a single-channel 10 Tbit/s Nyquist pulse transmission over 300 km, which was enabled by generation of subpicosecond Nyquist pulses and their dispersion compensation up to higher order and ultrafast demultiplexing. We also developed a bi-directional digital coherent transmission system with an injection-locked homodyne receiver, and demonstrated 80 Gbit/s, 256 QAM transmission with a loss budget of 14 dB. This result indicates the applicability of digital coherent technologies to high-speed mobile fronthaul.

(2) 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 high speed semiconductor laser introducing hybrid modulation scheme is being continued. It was confirmed numerically and experimentally that the frequency chirp in generated high speed optical signal by the laser which determines the transmission performance in long-haul optical fiber can be reduced drastically. A study on electron spin polarization controlled VCSEL is also progressing to realize very high speed lasing mode's polarization switch. It was confirmed that the modulation sensitivity can be enhanced at the vicinity of the frequency coincident with a birefringence-induced polarization mode splitting under the electron spin polarization modulation, which leads to a wide modulation bandwidth of the VCSEL not limited by the relaxation oscillation frequency. A wide 3-dB bandwidth of 23 GHz was experimentally confirmed by utilizing an optical spin polarization modulation technique.

(3) 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. The covered areas of us are all technical fields from the lower to higher layers, i.e., signal processing, RF/Mixed-signal device, antenna, MODEM, and network technologies. This year, we have investigated (1) a millimeter-wave wireless body area network (WBAN) to realize broadband and reliable communication and (2) non-orthogonal multiple access (NOMA) for increasing capacity of next-generation wireless communication systems such as 5G (5th generation mobile communication system).

(4) 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.

(5) 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 graphene laser-transistor featured with our original asymmetric dual-grating gates demonstrating coherent amplification of THz radiation with the maximal gain of 9% at room temperature promoted by graphene plasmon instabilities driven by dc-channel current flow. Second, for the realization of photonics-electronics convergence devices, we introduced a photoabsorption structure of a unitraveling-carrier photodiode into an InGaAs-channel high-electron-mobility transistor and successfully demonstrated the enhancement of the gain of the frequency down-conversion from 1.5-μm optical data signal to millimeter-wave data signal by more than three orders of magnitude.

(6) Quantum-Optical Information Technology

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

In 2018, we have achieved (1) generation of frequency-entangled photons with two-period PPLN crystal, (2) development of a novel sensor for mg-scale gravity measurements, (3) observation of local-field effects on optical coherent transients of semiconductor bound excitons, and (4) controlled introduction of nano and micro particles to a nanofiber surface and the measurement of the chiral polarization response.

Research Laboratory of Ultrahigh-Speed Optical Communication

Toward Innovative Optical Transmission from Backbone to Access Networks

Research Area of Ultrahigh-Speed Optical Transmission Toshihiko Hirooka, Professor

[Research Target and Activities]

Advanced global ICT services such as ultrahigh-definition video transmission and ultra-realistic communication cannot be realized without high-speed and large-capacity optical transmission systems. At the same time, optical transmission schemes with high spectral efficiency are crucial in terms of the maximum utilization of limited bandwidth resources. In our laboratory, we are engaged in research on ultrahigh-speed optical transmission using optical time division multiplexing with a single-channel Tbit/s-class capacity, digital coherent QAM optical transmission, and high-speed and spectrally efficient optical transmission by combining these two approaches. With a view to supporting innovative new ICT services such as 5G and IoT, our goal is also to apply digital coherent transmission to access networks and mobile fronthaul, and to develop novel transmission schemes integrating optical and wireless communications. This year, we successfully achieved a single-channel 10 Tbit/s Nyquist pulse transmission over 300 km, which was enabled by generation of subpicosecond Nyquist pulses and their dispersion compensation up to higher order and ultrafast demultiplexing (Fig. 1). We also developed a bi-directional digital coherent transmission system with an injection-locked homodyne receiver, and demonstrated 80 Gbit/s, 256 QAM transmission with a loss budget of 14 dB. This result indicates the applicability of digital coherent technologies to high-speed mobile fronthaul.

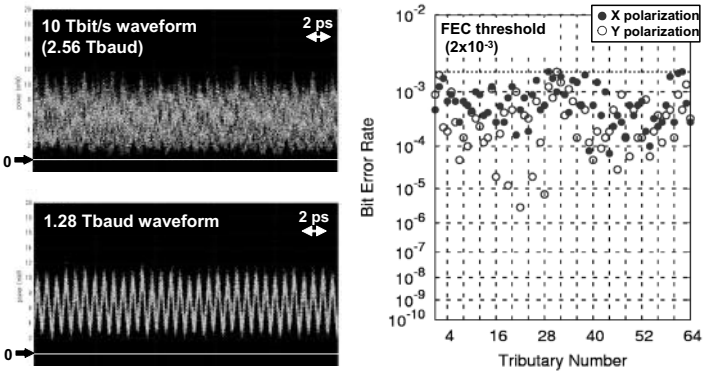

Fig. 1. 10 Tbit/s Nyquist pulse waveform and 300 km transmission result.

[Staff]

Professor: Toshihiko Hirooka, Dr.
Assistant Professor: Keisuke Kasai, Dr.
Research Fellow: Hisao Kuroda

[Profile]

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 a 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.

[Papers]

[1] M. Nakazawa, M. Yoshida, M. Terayama, S. Okamoto, K. Kasai, and T. Hirooka, "Observation of guided acoustic-wave Brillouin scattering noise and its compensation in digital coherent optical fiber transmission," Opt. Express vol. 26, no. 7, pp. 9165-9181, April (2018).
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Applied Quantum Optics

Research on Innovative Highly Functional Photonic Semiconductor Devices

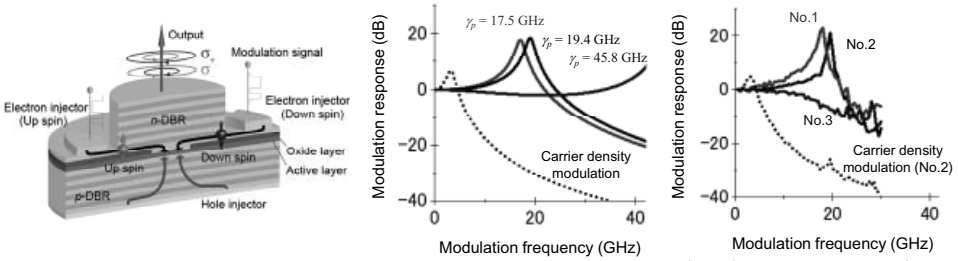
Highly Functional Photonics Hiroshi Yasaka, Professor
High accuracy optical measurement Masato Yoshida, Associate Professor

[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 studies on ultra-high-speed semiconductor lasers are being continued. It was confirmed that high speed lasing mode's polarization switch can be realized by utilizing electron spin polarization modulation in an active region of VCSEL which reads to a wide operation bandwidth not limited by the relaxation oscillation frequency.

Furthermore the study on compact and narrow linewidth semiconductor laser sources is also being proceeded by applying the optical negative feedback technology we proposed.



Schematic structure of spin polarization modulation VCSEL (left), calculated (center) and measured (right) responses of VCSEL under electron spin polarization modulation.

[Staff]

Professor : Hiroshi Yasaka, Dr.
Associate Professor : Masato Yoshida, 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.

Masato Yoshida received Ph.D. degree in electronic engineering from Tohoku University in 2001. In 2001, he joined the Research Institute of Electrical Communication, Tohoku University. He is currently an Associate Professor of the Institute. He has been engaging in research on fiber lasers and their application to optical measurements.

[Papers]

[1] M. Kanno, S. Mieda, N. Yokota, W. Kobayashi, and H. Yasaka, "Chirp Control of Semiconductor Laser by Hybrid Modulation Scheme (invited)," IEICE Transactions on Electronics, vol. E101-C, No. 7, pp. 561-565, 2018. / DOI 10.1587/transele.E101.C.561

[2] K. Aoyama, N. Yokota, and H. Yasaka, "Strategy of optical negative feedback for narrow linewidth semiconductor lasers," Optics Express, vol. 26, No. 16, pp. 21159-21169, 2018. / DOI 10.1364/OE.26.021159

[3] N. Yokota, K. Nisaka, H. Yasaka, and K. Ikeda, "Spin polarization modulation for high-speed vertical-cavity surface-emitting lasers," Applied Physics Letters, vol. 113, Issue 17, 171102, 2018. / DOI 10.1063/1.5040914

Advanced Wireless Information Technology

For realization of the next generation mobile network

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

[Research Target and Activities]

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

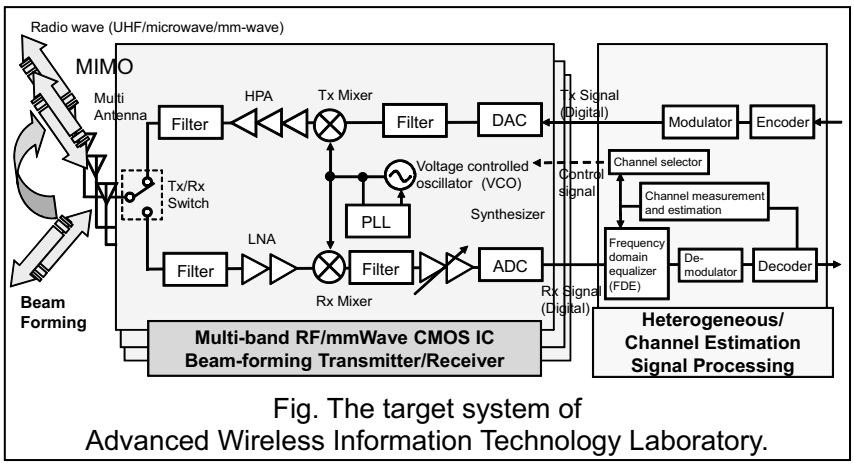


Fig. The target system of
Advanced Wireless Information Technology Laboratory.

This year, we have mainly investigated (1) a millimeter-wave wireless body area network (WBAN) to realize broadband and reliable communication and (2) non-orthogonal multiple access (NOMA) for increasing capacity of next-generation wireless communication systems such as 5G (5th generation mobile communication).

[Staff]

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

[Profile]

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

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

[Papers]

[1] K. Akimoto, *et al.*, "Measurement of on-body propagation loss for directional millimeter-wave WBAN," in Proc. Global Symposium on Millimeter Waves (GSMM) 2018, May 2018
[2] N. Takeda, *et al.*, "A study of inductive coupling wireless power transfer for IC chips on tablets in a pill case," in Proc. Asian Wireless Power Transfer Workshop (AWPT), Nov. 2018
[3] K. Mayama, *et al.*, "Evaluation of link level performance considering EVM of transmit signal for downlink NOMA," in Proc. 2018 Asia Pacific Microwave Conference (APMC), Nov. 2018
[4] J. Zhang, *et al.*, "A 26GHz-band image enhancement type 1-bit DAC for direct digital RF 1-bit modulator," in Proc. 2018 Asia-Pacific Microwave Conference (APMC), Nov. 2018
[5] S. Kameda, *et al.*, "Random access control scheme with reservation channel for capacity expansion of QZSS safety confirmation system," IEICE Trans. Fundamentals, vol.E102-A, no.1, pp.186-194, Jan. 2019

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Information Storage Systems

High Density and High Speed Energy-Assisted Magnetic Recording

Information Storage Systems: 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 research was concentrated on microwave-assisted magnetic recording (MAMR), with additional work on heat-assisted magnetic recording (HAMR). Modeling of magnetoresistive random access memories (MRAM) was also carried out.

In a MAMR system it is possible to record information on a medium consisting of multiple, discrete storage layers by utilising 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 the appropriate storage layer, enabling selective recording on that layer only. The work in [2] describes how to optimise a dual layer system by introducing anti-ferromagnetic coupling between the recording layers to mitigate magnetostatic interactions between the layers. The work in [3] demonstrates magnetic recording using only a spin torque oscillator. Switching of magnetic grains with an exchange-coupled composite structure was shown to be possible under a wide range of conditions. A review of heat assisted magnetic recording is given in [4].

[Staff]

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

[Profile]

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

[Papers]

[1] S. J. Greaves, Y. Kanai and H. Muraoka, "Antiferromagnetically coupled media for microwave-assisted magnetic recording", IEEE Transactions on Magnetics 54(2), 3000111-1-11, (2018), doi 10.1109/TMAG.2017.2730881.

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[3] S. J. Greaves, "Magnetic recording using a spin torque oscillator", IEEE Transactions on Magnetics 54(11), 3001705-1-5, (2018), doi 10.1109/TMAG.2018.2834933.

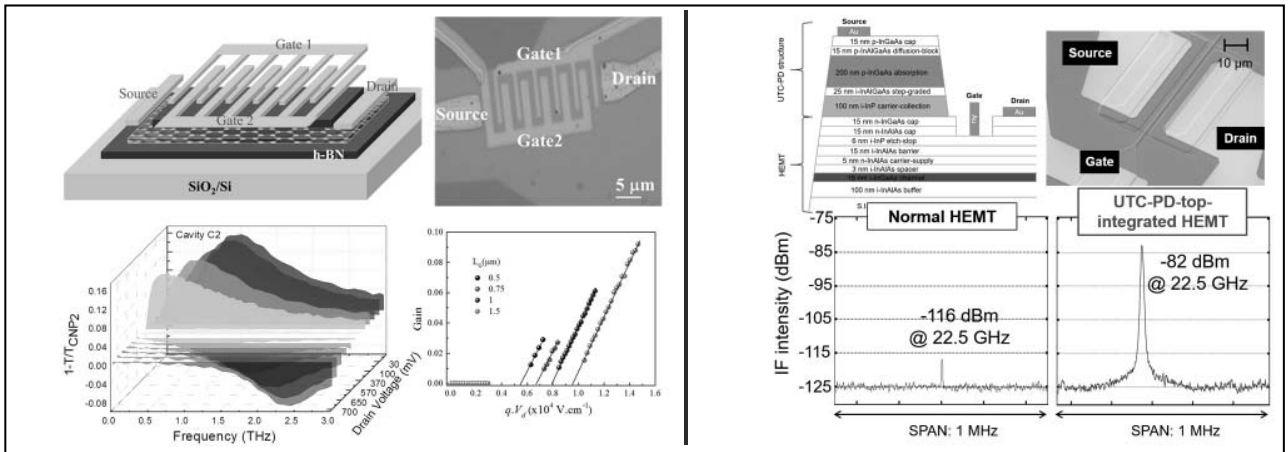
[4] S. J. Greaves: "Ultra-Fast Dynamics for Heat-Assisted Magnetic Recording", Handbook of Materials Modeling Volume 2: Applications: Current and Emerging Materials, editors W. Andreoni and S. Yip, Springer, Cham, 2018. doi 10.1007/978-3-319-50257-1_106-1, ISBN 978-3-319-50257-1 (Online).

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: Schematic image of an asymmetric dual-grating gate graphene-channel FET and microscope image of a fabricated device (top), extinction/gain spectra measured at room temperature demonstrating coherent amplification of THz radiation (bottom left, negative value for gain), and the drain-voltage dependence of the maximum gain (bottom right), right: a cross-sectional structural drawing of a UTC-PD-integrated-HEMT for the optical-to-wireless carrier frequency down-conversion and its SEM image (top), comparison of output intensities of down-converted IF signals at 22.5 GHz from 1.5-μm optical signals using a normal HEMT and the UTC-PD-integrated HEMT (bottom).

We are developing novel, integrated electron devices and circuit systems operating in the terahertz (THz) region. First, towards the creation of novel current-injection graphene THz laser-transistors, we developed a graphene laser-transistor featured with our original asymmetric dual-grating gates demonstrating coherent amplification of THz radiation with the maximal gain of 9% at room temperature promoted by graphene plasmon instabilities driven by dc-channel current flow. Second, for the realization of photonics-electronics convergence devices, we introduced a unitraveling-carrier photodiode structure into an InGaAs-channel high-electron-mobility transistor and successfully demonstrated the enhancement of the gain of the frequency down-conversion from 1.5-μm optical signal to millimeter-wave signal by more than three orders of magnitude.

[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] Y. Omori, T. Hosotani, T. Otsuji, K. Iwatsuki, and A. Satou, "UTC-PD-integrated HEMT for optical-to-millimeter-wave carrier frequency down-conversion," OFC: Optical Fiber Conference Dig., Th3B.5, pp. Th3B.5-1-3, 2019. [2] S. Boubanga-Tombet, D. Yadav, W. Knap. V.V. Papov, and T. Otsuji, "Terahertz light amplification by current-driven plasmon instabilities in graphene," CLEO: Int. Conf. on Lasers and Electro-Optics Dig., SW4D.4, 2018. [3] I. Gayduchenko, G. Fedorov, M. Moskotin, D. Yagodkin, S. Seliverstov, G. Gol'tsman, A. Kuntsevich, M. Rybin, E. Obraztsova, V. Leiman, M. Shur, T. Otsuji, and V. Ryzhii, "Manifestation of plasmonic response in the detection of sub-terahertz radiation by graphene based devices," Nanotechnology, vol. 29, pp. 245204-1-8, 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 2018, we have achieved (1) generation of frequency-entangled photons with two-period PPLN crystal, (2) development of a novel sensor for mg-scale gravity measurements, (3) observation of local-field effects on optical coherent transients of semiconductor bound excitons, and (4) controlled introduction of nano and micro particles to a nanofiber surface and the measurement of the chiral polarization response.

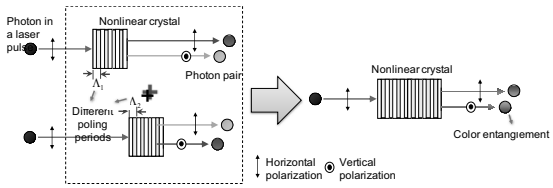


Fig. 1. An illustration of the scheme for producing frequency-entangled photons. A nonlinear crystal has two different poling periods so that produced photon pairs with orthogonally polarized photon pairs can be frequency entangled.

[Staff]

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

[Profile]

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

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

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

[Papers]

[1] Y. Mitsumori, S. Watanabe, K. Asakura, K. Seki, K. Edamatsu, K. Akahane, and N. Yamamoto, "Effect of the depolarization field on coherent optical properties in semiconductor quantum dots", Phys. Rev. B **97**, 235305 (2018)
[2] F. Kaneda, H. Suzuki, R. Shimizu, and K. Edamatsu, "Direct generation of frequency-bin entangled photons via two-period quasi-phase-matched parametric downconversion", Opt. Exp. **27**, 001416 (2019)
[3] N. Matsumoto, S. B. Cataño-Lopez, M. Sugawara, S. Suzuki, N. Abe, K. Komori, Y. Michimura, Y. Aso, and K. Edamatsu, "Demonstration of Displacement Sensing of a mg-Scale Pendulum for mm- and mg- Scale Gravity Measurements", Phys. Rev. Lett. **122**. 071101 (2019)

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, (7) Multimodal Cognitive System Laboratory.

The goals and achievements in the fiscal year 2018 of each laboratory are described in detail below.

(1) Electromagnetic 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 ultra-low noise. The obtained proto-type system shows extra-high sensitivity compare with the commercial products. 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 is going on the commercialization with the corroborated work with a company. 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

(Aims) To propose high-definition communication systems that convey a 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 focused on the auditory attention mechanism from various points of view.

The effects of spatio-temporal cues on the understanding of a speech target were quantitatively characterized through psychophysical experiments. Moreover, it was observed that when the listeners' attention is drawn to a specific distance, they are able to identify an auditory target presented from same distance faster than when it is presented from elsewhere. These findings could be applied to the diagnosis of auditory processing disorders (APD). In addition, we develop advanced acoustic systems, such as 3D virtual auditory displays, sound acquisition and presentation systems. We proposed a modeling method for head-related transfer functions (HRTFs), an important component in binaural systems, based on the spherical wavelet transform. The proposed method can effectively express the local characteristics of HRTFs. We also evaluated the extension and coloration of multiple listening zones synthesized by our proposed shared auditory-field reproduction system.

(3) Visual Cognition and Systems

(Aims) To understand the vision-related brain functions in order to apply the knowledge to realize human oriented information communication systems.

(Achievements) We achieved results in the fields of implicit learning of visual environments through body movements and illusory visual perception of object orientations. Firstly, we investigated the ability to process spatial information surrounding the viewer visually in the condition where not all information can be processed simultaneously. To investigate the function, we developed an experimental procedure, where the observer searched a target in the 360° visual, moving the body, the head and the eyes. The results showed that the visual system obtains spatial information surrounding the viewer without explicit knowledge by repeated visual searches. Secondly, we found a new visual illusion of object orientation. When a rotating object (inducer) is briefly replaced by a static face image (test stimulus), the orientation of the face appears to shift in the rotation direction of the inducer (object orientation induction, OOI). The OOI suggests that there is a predictive process that continuously analyzes and updates the orientation of rotating objects, independently of their identification.

(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 contributed novel spatial user interfaces. First, we proposed and prototyped a transformable digital table by combining modular self-actuated tables that physically and spatially adapts its shape to user's physical characteristics. Second, we created a novel intuitive world

building tool in virtual reality using metaphors of world-tree and blocks. Finally, we proposed Redirected jumping, a novel locomotion method in immersive room-scale virtual environment, enabling imperceptible manipulations of user's jumping motions and their distance/direction perceptions.

(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 2018 are summarized as follows: (1) we have elucidated the gait transition mechanism in centipedes through mathematical modeling based on behavioral observations; (2) we have proposed a minimal model for body-limb coordination of quadrupeds and have developed a robotic platform to validate it; (3) we have improved the *Tegotae*-based control model for undulatory locomotion which we proposed previously, and have succeeded in enlarging adaptable environments; (4) we have succeeded in elucidating the decision making mechanism of brittle stars through mathematical modeling based on behavioral experiments wherein the nerve ring is partially transected.

(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) Mechanically stable lipid bilayers were formed on microfabricated silicon chips that had amphiphobic surfaces through surface modification. We succeeded in reconstitution of cardiac hERG channel proteins into the lipid bilayers and recording their activities at the single-channel level. We also showed that by implementing modular organization to cultured cortical neurons, their network can be tuned to generate much richer in dynamics both spatially and temporally. Another achievement is fabrication of a novel photo-sensing device based on a hybrid of phospholipid bilayers and organic semiconductor molecules.

(7) Multimodal Cognitive System Laboratory

(Aims) This group aims to study the basic mechanisms underlying multimodal cognitive systems, including vision, audition, tactile sensation, gustation and olfaction, together with the related groups such as the Advanced Acoustic Information Systems and the Visual Cognition and Systems groups.

(Achievements) In this year, we have done some experiments about the followings; the effect of odors of fabric softeners on perception and estimation of female faces, the effects of visually presented brand information on perception of coffee flavor, the interactions between color and flavor in food recognition, etc. We have also started the cognitive studies about interaction of the intention and/or the cognition for the actions with the perception.

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. Imaging sensitivity of high frequency magnetic field measuring system 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 optimization of structure for obtaining high sensitivity was carried out for high frequency carrier type magnetic sensor.

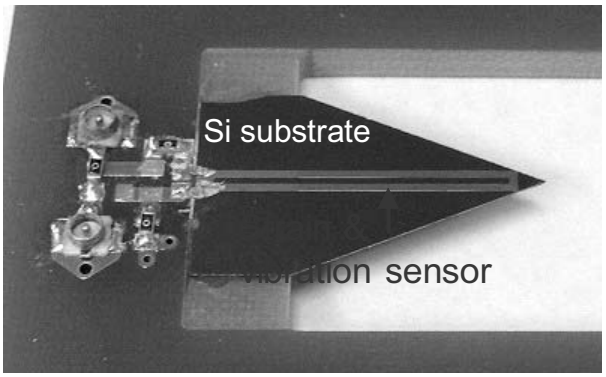


Fig. 1 Strain and vibration sensor using inverse-magnetostrictive effect.

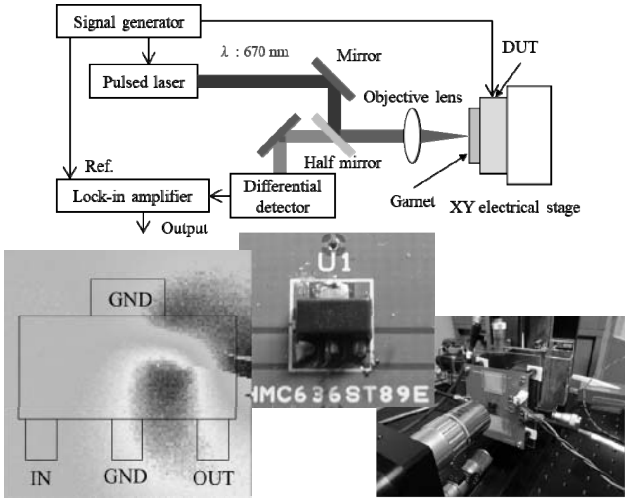


Fig. 2 High frequency magnetic field measuring system using magneto-optical crystal probe

[Staff]

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

[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] Yuito Kubo, Shuichiro Hashi, Hajime Yokoi, Kaoru Arai, Kazushi Ishiyama, " Development of Strain and Vibration Sensor using Magnetostriction of Magnetic Thin Film," IEEJ Transactions on Sensors and Micromachines, Vol. 138, No. 4, pp. 153-158 (2018).

[2] Jingyan Ma, Sho Muroga, Yasushi Endo, Shuichiro Hashi Hiroo Yokoyama Yoshiaki Hayashi, Kazushi Ishiyama, "Analysis of Magnetic Film-Type Noise Suppressor Integrated on Transmission Lines for On-Chip Crosstalk Evaluation," IEEE Transactions on Magnetics, Vol. 54, No. 6, 2800404 (2018).

[3] Shun Fujieda, Shimpei Asano, Shuichiro Hashi, Kazushi Ishiyama, Tsuguo Fukuda, Shigeru Suzuki, "Significant reduction in Young's modulus of Fe-Ga alloy single crystal by inverse magnetostrictive effect under tensile stress," Journal of Applied Physics, Vol. 124, 233901 (2018).

[4] Hiroo Yokoyama, Kosuke Kusunoki, Yoshiaki Hayashi, Shuichiro Hashi, Kazushi Ishiyama, "Magneto-impedance properties of thin-film type sensors using CoNbZr/SiO2 multilayer films," Journal of Magnetism and Magnetic Materials, Vol. 478, pp. 38-42, (2019).

Advanced Acoustic Information Systems Laboratory

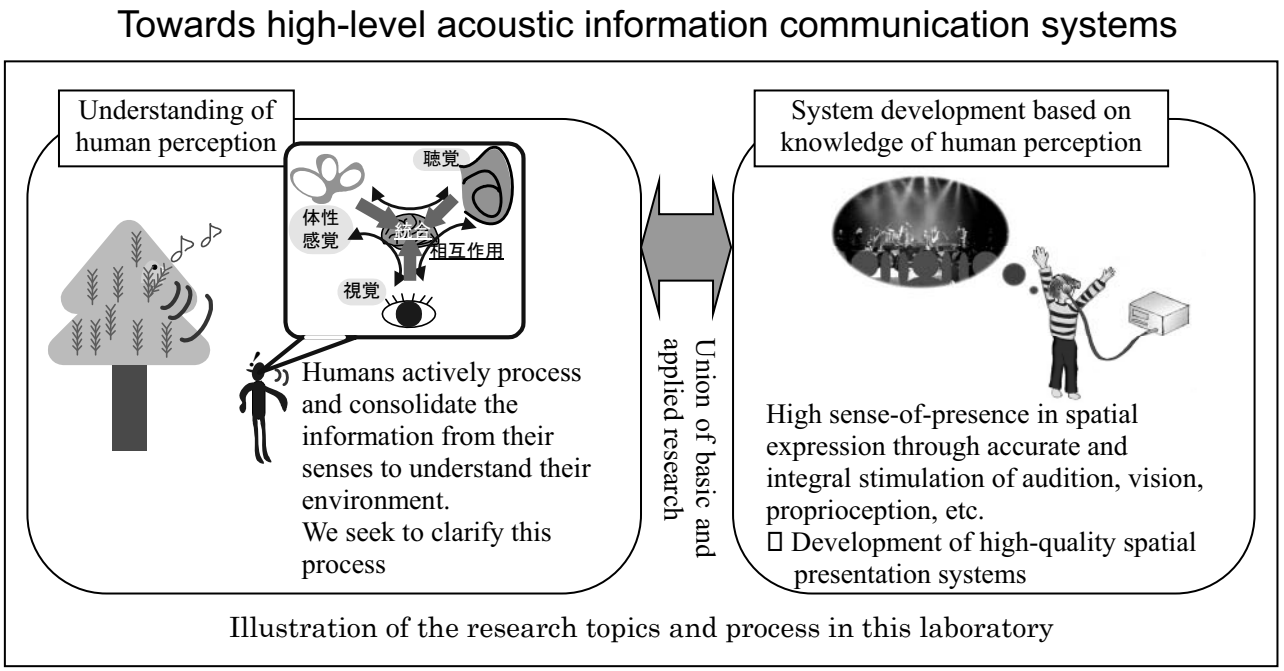


Illustration of the research topics and process in this laboratory

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

[Research target]

Our research goal is to clarify the how humans process information through "hearing," which is one of the most important modalities in human perception. In addition, we investigate the multimodal processing of auditory and visual information, as well as proprioception. Our findings are applied towards the development of advanced acoustic communication systems and user interfaces, including the realistic and comfortable expression of three-dimensional sound spaces.

[Activities of 2018]

1. Understanding of hearing and its related multimodal sensory information perceptual processes.

Humans form stable and accurate mental images of their external environment by integrating information from multiple senses. Within this context, our research focuses on the role of audition and related multimodal sensory information processing. During the fiscal year 2018, we pursued research on the perception of spatial sound during self-motion, achieving several new findings. In particular, we examined the relationship between rotational motion and stimulus duration in horizontal sound image localization. We found it possible for sound image localization performance to be improved through active listening. Further, duration of the auditory stimulus was not found to be as important for accurate sound localization as previously thought. This result was published as a journal article [1].

Contact to Associate Professor Shuichi SAKAMOTO : saka@ais.riec.tohoku.ac.jp

2. Research on 3D sound space perception, as well as its and control and reproduction

Three-dimensional sound recording and reproduction are critical to convey high-level perceptual information, such as the sense-of-presence, in communication systems. During fiscal year 2018 we proposed the theory of Boundary Matching Filters to calculate optimal loudspeaker driving signal for spatial sound reproduction. The proposal relies on the spherical harmonic expansion to match a recording boundary, sampled using microphones, to a reproduction one. This result was published in an international journal [2].

3. Kansei evaluation of auditory and multimodal space

Next-generation communication systems are expected to present virtual environments in a realistic "as if you were there" fashion. To achieve this goal, it is necessary to elucidate the processes involved in human perception of the external environment through our various senses. In fiscal year 2018, we looked into the difference between sense-of-presence, the feeling of "being there," and verisimilitude, the impression of being "the real thing." To this end, we conducted perceptual experiments using multimodal contents, including vibration. In particular, we compared the performance of real-world vibration information to that of synthetic one derived from sound recordings at the scene. The synthetic vibration was shown to convey high-level kansei information to the same degree as the real-world measurement. Further, in some cases the synthetic vibration can achieve a higher score in verisimilitude evaluations. These results were published as an invited paper in an academic journal [3].

[Staff]

Professor: Yôiti Suzuki (since 1999)
Associate professor: Shuichi Sakamoto (since 2011)
Assistant professors: Zhenglie Cui, Jorge Trevino
Specially appointed assistant professor: Cesar Daniel Salvador
Technical Staff: Fumitaka Saito
Secretaries: Miki Onodera, Makiko Minowa

[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.

[Selected publications of fiscal year 2018]

[1] A. Honda, S. Tsunokake, S. Sakamoto and Y. Suzuki , “Effects of listener's whole-body rotation and sound duration on horizontal sound localization,” Acoustical Science and Technology, 39(4), 305-307 (2018).

[2] C. D. Salvador, S. Sakamoto, J. Trevino and Y. Suzuki, “Boundary matching filters for spherical microphone and loudspeaker arrays,” IEEE Transactions on Audio, Speech and Language Processing, 26(3), 461-474 (2018).

[3] Z. Cui, H. Yagyu, S. Sakamoto, Y. Suzuki and J. Gyoba, "How can body vibration generated from audio signal in AV content enhance perceived reality?," Journal of Information Processing Society of Japan, 59(11), 1986-1994 (2018) (in Japanese)

[4] S. Sakamoto, T. Miyashita, Z. Cui, M. Morimoto, Y. Suzuki and H. Sato, “Effects of inter-word pauses on speech intelligibility under long-path echo conditions,” Applied Acoustics, 140, 263-274 (2018).

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 implicit learning and object perception.

Firstly, we investigated the ability to process spatial information surrounding the viewer visually in the condition where not all information can be processed simultaneously. To investigate the function, we developed an experimental procedure, where the observer searched a target in the 360° visual field, moving the body, the head and the eyes. The results showed that the visual system obtains spatial information surrounding the viewer without explicit knowledge by repeated visual searches. Secondly, we found a new visual illusion of object orientation perception. When a rotating object (inducer) is briefly replaced by a static face image (test stimulus), the orientation of the face appears to shift in the rotation direction of the inducer (object orientation induction, OOI). We investigated the perception of object orientation in motion, examining potential factors that contribute to OOI and found that the phenomenon is general to objects rather than specific to faces; OOI could be observed with non-face objects. Further experimetns revealed that salient features are necessary, that neither the object shape nor its identity is important, and that OOI is a phenomenon in the pathway for fast visual processing. These results suggest that there is a predictive process that continuously analyzes and updates the orientation of rotating objects, independently of their identification.

Figure. Experimental setup to investigate implicit learning of surroundings

[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. In 2005, he joined Tohoku University and he has been a professor of Research Institute of Electrical Communication of Tohoku University since then.
Ichiro KURIKI Dr. Kuriki received Ph.D. degree from Tokyo Institute of Technology in 1996. After then, he worked at Imaging Science and Engineering Laboratory, Tokyo Institute of Technology as a research associate until October, 1999. He joined the Research Institute of Electrical Communication, Tohoku University as an Associate Professor in January, 2006.
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] S. Shioiri, K. Hashimoto, K. Matsumiya, I. Kuriki, S. He, (2018), Extracting the orientation of rotating objects without object identification: Object orientation induction, Journal of vision 18 (9), 17-17
[2] S. Shioiri, M. Kobayashi, K. Matsumiya, I. Kuriki, (2018), Spatial representations of the viewer's surroundings, Scientific reports 8 (1), 7171
[3] Tseng, C.H., Chow, H.M., Ma, Y.K. and Ding, J. (2018) Preverbal infants utilize cross-modal semantic congruency in artificial grammar acquisition, Scientific Report, 8:12707.

Information Content

Technologies for Interactive Content

Interactive Content Design	Yoshifumi KITAMURA,	Professor
Human-Content Interaction	Kazuki TAKASHIMA,	Associate Professor

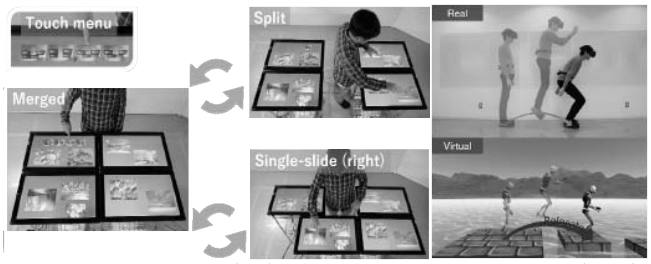
[Research Target and Activities]

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.

In this year, we proposed a transformable digital table using modular self-actuated tables that physically adapts its shape to user's physical characteristics [1]. We also created a novel VR world building tool using metaphors of world-tree and blocks [2], and explored Redirected jumping technique that enables imperceptibly manipulate user's perceptions during jump motions [3].

[Staff]

Professor: Yoshifumi Kitamura, Dr.
Associate Professor: Kazuki Takashima, Dr.
Assistant Professor: Kazuyuki Fujita, Dr.



Transformable tabletop (left) and Redirected jumping in VR (right)

[Profile]

Yoshifumi Kitamura: Since 2010, he has been Professor in the Research Institute of Electrical Communication, Tohoku University. 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).

Kazuki Takashima: Dr. Takashima received his Ph.D from the Graduate School of Information Science and Technology at Osaka University in 2008. He then worked as an assistant professor at Osaka University, and joined Tohoku University's Research Institute of Electrical Communication as an assistant professor in 2011. Dr. Takashima was promoted to the rank of associate processor at Tohoku University in 2018.

[Papers]

[1] Yoshiki Kudo, Kazuki Takashima, Morten Fjeld and Yoshifumi Kitamura, AdapTable: Extending Reach over Large Tabletops through Flexible Multi-Display Configuration, Proc. of ACM Conference on Interactive Surfaces and Spaces, 213-225, November 2018.

[2] Shotaro Ichikawa, Kazuki Takashima, Anthony Tang and Yoshifumi Kitamura, VR Safari Park: A Concept-based World Building Interface using Blocks and World Tree, Proc. of ACM Symposium on Virtual Reality Software and Technology, 6, 5page, November 2018.

[3] Daigo Hayashi, Kazuyuki Fujita, Kazuki Takashima, Robert W. Lindeman and Yoshifumi Kitamura, Redirected Jumping: Imperceptibly Manipulating Jump Motions in Virtual Reality, Proc. of IEEE Conference on Virtual Reality and 3D User Interfaces, 10 pages, 2019.

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Real-world Computing

Toward Understanding Design Principle for Life-like Resilient Systems

Real-world Computing Akio Ishiguro, Professor

[Research Target and Activities]

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

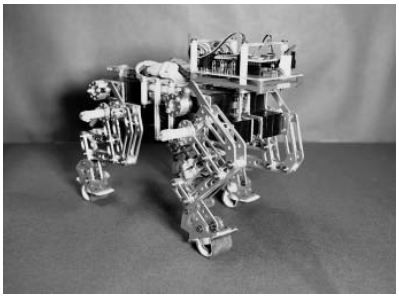


Fig.1: Quadruped robot that exhibits versatile high-speed gaits

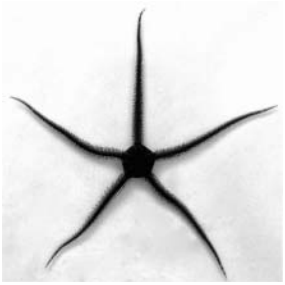


Fig.2: Ophiuroid nerve ring that generates adaptive inter-arm coordination

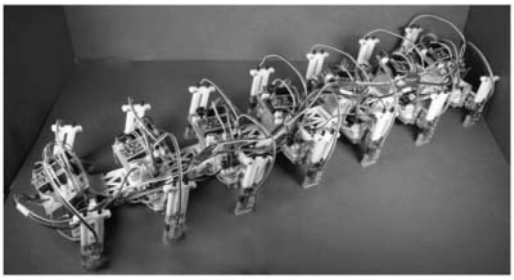


Fig.3: Sea roaches-like robot that exhibits body bending to achieve faster locomotion speed.

[Staff]

Professor: Akio ISHIGURO, Dr.
Associate Professor: Takeshi KANO, Dr.
Assistant Professor: 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] A.Fukuhara, D. Owaki, T. Kano, R. Kobayashi, and A. Ishiguro, " Spontaneous gait transition to high-speed galloping by reconciliation between body support and propulsion," in Advanced Robotics, vol. 32, 794-808, 2018

[2] E. G. Clark, D. Kanauchi, T. Kano, H. Aonuma, D. E. G. Briggs, and A. Ishiguro, " The function of the ophiuroid nerve ring: how a decentralized nervous system controls coordinated locomotion," Journal of Experimental Biology, (2019) 222, jeb192104. doi:10.1242/jeb.192104

[3] T. Kano, Y. Ikeshita, A. Fukuhara, and A. Ishiguro, "Body-limb coordination mechanism underlying speed-dependent gait transitions in sea roaches," Scientific Reports, 9:2848(2019), doi: 10.1038/s41598-019-39862-3

Nano-Bio Hybrid Molecular Devices

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

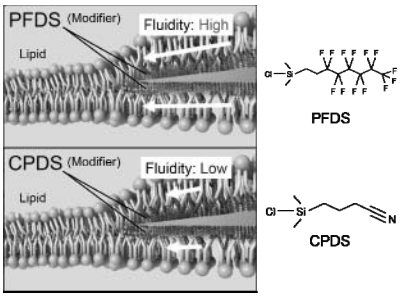
Nano-Bio Hybrid Molecular Devices: Ayumi Hirano-Iwata, Professor

[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. Stabile lipid bilayers in microfabricated chips having amphiphobic surfaces

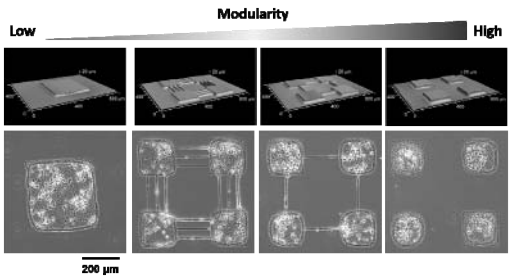
Mechanically stable lipid bilayers were formed on microfabricated silicon chips that had amphiphobic surfaces through surface modification. We also succeeded in reconstitution of cardiac hERG channel proteins into the lipid bilayers and recording their activities at the single-channel level. [Langmuir, **34**, 5615-5622 (2018).]



Formation of stable lipid bilayers on amphiphobic septa.

2. Reconstruction of artificial neuronal networks

Surface engineering offers an effective solution to bridge the in vivo-in vitro gap in neuroscience. Our recent work showed that by implementing modular organization to cultured cortical neurons, their network can be tuned to generate much richer in dynamics both spatially and temporally. [Sci. Adv. **4**, eaau4914 (2018).]



Engineered neuronal networks with modular organization.

3. Novel devices based on a hybrid of a phospholipid bilayer and organic semiconductor molecules

A hybrid membrane was formed by doping a lipid bilayer with organic semiconductor molecules. Using these hybrid membranes, a photo-sensing device was formed on micro-fabricated silicon chips. It was demonstrated that the device shows high performances owing to the ultra-thin thickness of the lipid bilayer structure. [J. Electroanal. Chem., **832**, 55-58 (2019).]

[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. Yamaura, D. Tadaki, S. Araki, M. Yoshida, K. Arata, T. Ohori, K. Ishibashi, M. Kato, T. Ma, R. Miyata, H. Yamamoto, R. Tero, M. Sakuraba, T. Ogino, M. Niwano, A. Hirano-Iwata, "Amphiphobic septa enhance the mechanical stability of free-standing bilayer lipid membranes", Langmuir, **34**, 5615-5622 (2018).

[2] H. Yamamoto, S. Moriya, K. Ide, T. Hayakawa, H. Akima, S. Sato, S. Kubota, T. Tanii, M. Niwano, S. Teller, J. Soriano, A. Hirano-Iwata, "Impact of modular organization on dynamical richness in cortical networks", Sci. Adv., **4**, eaau4914 (2018).

[3] K. Kanomata, T. Deguchi, T. Ma, T. Haseyama, M. Miura, D. Yamaura, D. Tadaki, M. Niwano, A. Hirano-Iwata, F. Hirose, "Photomodulation of electrical conductivity of a PCBM-doped free-standing lipid bilayer in buffer solution", J. Electroanal. Chem., **832**, 55-58 (2019).

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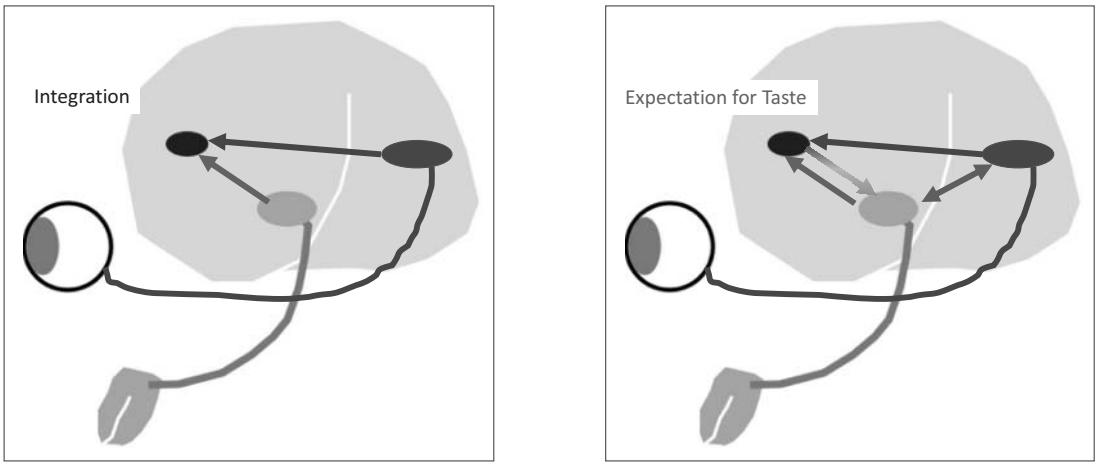
Multimodal Cognitive System Division

Research project on multimodal information integration based on food perception.



Classical Bottom-Up model for perception of food

Top-down model for perception of food in this research

Fig. 1 The model adapted in this research is shown in right panel. The perception of food is based on interactive top-down processing of multimodal sensory inputs, not on simple integration of sensory inputs.

Nobuyuki Sakai, Dr. Professor

[Research Target and Activities]

In this year, we have done some experiments about the followings; the effect of odors of fabric softeners on perception and estimation of female faces, the effects of visually presented brand information on perception of coffee flavor, the interactions between color and flavor in food recognition, etc. We have also started the cognitive studies about interaction of the intention and/or the cognition for the actions with the perception.

[Staff]

Professor : Nobuyuki Sakai, Dr.
Assistant Professor : Kosuke Yamamoto

[Profile]

Nobuyuki Sakai graduated from Graduate School of Human Sciences, Osaka University in 1998. Then he worked at Hiroshima Shudo University and National Institute of Advanced and Industrial Science and Technology (AIST) , Kobe Shoin Women's University. He, then, moved to Sendai in October 2011, and he is a professor of Graduate School of Arts and Letters of Tohoku University now.

[Papers]

[1] Takuya Onuma, Hiroaki Maruyama, and Nobuyuki Sakai Enhancement of Saltiness Perception by Monosodium Glutamate Taste and Soy Sauce Odor: A Near-Infrared Spectroscopy Study. Chemical Senses, Volume 43, Issue 3, Pages 151–167 (2018)
[2] Takuya Onuma and Nobuyuki Sakai Fabric Softener Fragrances Modulate the Impression Toward Female Faces and Frontal Brain Activity. Japanese Psychological Research, 60(4), 276-287 (2018)
[3] Hiroshi Shibata, Takuya Onuma, Yasuhiro Takeshima, Yuwadee Penwannakul, and Nobuyuki Sakai Role of the Right Dorsolateral Prefrontal Cortex in the Cognitive Process of Matching Between Action and Visual Feedback. Japanese Psychological Research, 60(4), 288-299 (2018)

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. With the reorganization of RIEC in FY2016, 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. 2018 to Mar. 2019 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 result of the 2018 academic year is the development of a novel type theory for "finitary polymorphism". We have defined a predicative second-order lambda calculus where each type abstraction is explicitly constrained to a finite type universe, and establishes the type soundness with respect to a type-passing operational semantics. Based on this novel type theory, we have developed an optimization method for compiling polymorphic languages and have implemented the method in the SML# compiler.

(2) Computing Information Theory

We proceed with studying a few models of computation and formal language theory which can be theoretical foundations for efficient development and static verification of software. First, we have implemented an algorithm for checking functional equivalence of tree transducers that is a formal model of recursive transformation over tree structured data and examined its practicability. Second, we have partially unraveled an interesting property of the function composition combinator in combinatory logic that is a classical model of computation. Additionally, we have proved an important theorem which verifies a variant of pumping lemmas to recognize a limitation of the expressiveness of higher-order languages.

(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 design the cooperation method of network administrators and a management system based on the concept of human-agent collectives, and confirmed effectiveness of the proposed method through experiment using an experiment system. Moreover, we proposed a collaboration method of a human and an information system and implemented an experiment system in the field of education and training. Using the system, we verified usefulness of the proposed method. In the research of the agent based IoT (AIoT) and its application, we continued the experimentation of the construction method of various AIoT devices based on the agentification method of IoT devices. Next, we implemented an experimental system of the evacuation guidance at disaster using AIoT drones, and verified effectiveness of the proposed system by the field experiment using the 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 world's lowest latency tamper-resistant PRINCE cipher hardware, and also developed a new efficient method for improving stability and uniformity of hardware-oriented physically unclonable functions used for individual identification and secret key generation. We have also developed a method for detecting malicious hardware (i.e., Hardware Trojan) that can be inserted into embedded systems, and developed a hardware function evaluation technology based on the developed method.

(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 analyzed performance and characteristics of the chaotic reservoir network composed of chaotic neurons, which we proposed last year, through chaotic time-series predictions. (ii) For large-scale chaotic optimization hardware, we designed and fabricated a switched-current chaotic neural network integrated circuit chip with TSMC 65 nm CMOS process. (iii) We studied a fast hardware implementation scheme of the random number generator based on the augmented Lorenz map.

(6) New Paradigm VLSI System

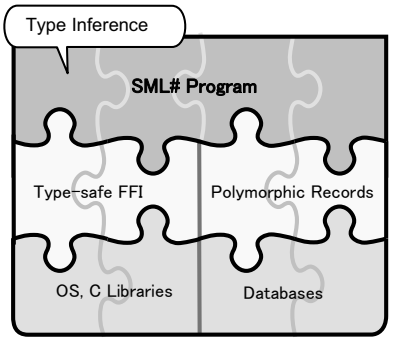
Our research activity is to solve the several limitations such as power dissipation, performance and reliability due to the present binary-CMOS-based VLSI computing. The key approach to breaking through such limitations is primarily the following two ways: the logic-in-memory architecture based on nonvolatile 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 firstly succeeded (1) to design and implement the magnetic tunnel junction (MTJ)-based nonvolatile microcontroller unit (MCU) for IoT (Internet of Things) sensor node applications. The use of MTJ-based storage elements, embedded nonvolatile field programmable gate array (FPGA), and power-gating technique makes it possible to greatly reduce wasted power. As a result, the proposed MCU has achieved the average power dissipation of 50 μW or less with performing the operation frequency of 200MHz. We have also (2) designed and evaluate a brain-inspired vision processor using stochastic computing for object-recognition applications. In case of HMAX (one of the brain-inspired object-recognition applications), its power dissipation has become 5 percent or less (1/20 or less) of that in a conventional binary-logic-based hardware realization, with maintaining the same operation accuracy and throughput as the conventional one. This-year research results including the above topics have reported 9 academic journal papers such as IEEE Trans. VLSI Systems, 9 peer-reviewed international conference papers, and 6 invited talks (4 invited talks in international conferences).

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 result of the 2018 academic year is the development of a novel type theory for *finitary polymorphism* as a foundation for optimizing polymorphic language compilers. We have defined a predicative second-order lambda calculus where each type abstraction is explicitly constrained to a finite type universe, and established the type soundness with respect to a type-passing operational semantics. Based on this novel type theory, we have developed an optimization method for compiling polymorphic languages and have implemented the method in the SML# compiler.

[Staff]

Professor : Atsushi Ohori, Ph.D.
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]

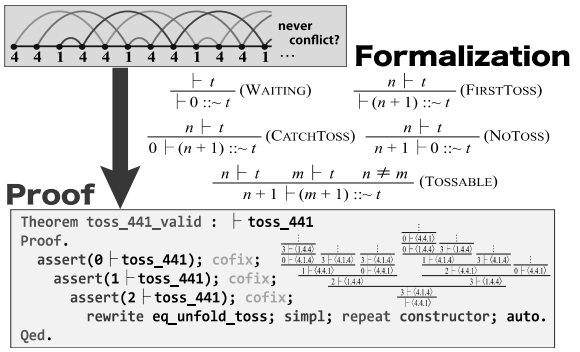
[1] Mifuyu Osaka, Katsuhiro Ueno, Atsushi Ohori: Typed template engine based on partially dynamic records (in Japanese), Computer Software, vol. 35, no, 3, pp. 3_79-3_95, 2018, DOI: 10.11309/jssst.35.3_79.
[2] Atsushi Ohori, Katsuhiro Ueno, Hisayuki Mima: Finitary Polymorphism for Optimizing Type-Directed Compilation, In Proceedings of the International Conference on Functional Programming (ICFP'18), 2018, DOI: 10.1145/3236776.
[3] Kazuki Ono, Katsuhiro Ueno, Atsushi Ohori: Implementation Method of Native Code Level Debugging Environment for SML# (in Japanese), Information Processing Society of Japan Transactions on Programming (PRO) , 11(3),1-13 (2018-09-20) , 1882-7802.

Computing Information Theory

Filling the Gap between Humans and Computers

Computing Information Theory Keisuke Nakano, Professor

[Research Target and Activities]



Notwithstanding that programming is one of the most typical methods for a human to communicate with a computer, there is a significant gap between programs that are recognizable for humans and those that are efficiently executed by computers. Programs described as humans think are highly readable but are not always efficient. On the other hand, programs described with carefully considering the behavior of computers show much better performance in time and space but are very complicated and hardly maintainable. Our ultimate goal is to fill the gap between humans and computers in programming.

More specifically, our research topics include *program transformation* and *program verification*. Program transformation is to automatically derive well-tuned and efficient programs from human-readable ones; Program verification is to statically (that is, without running) check if human-written but well-tuned complicated programs behave as the programmers expect for any input. To this end, we deeply study the theory of formal tree languages, such as tree automata and tree transducers, which has a close relationship with the program transformation and verification. Besides that, we are working on formalizing relevant results in mathematics and theoretical computer science on a proof assistant to make our theory more robust.

[Staff]

Professor : Keisuke Nakano, Dr.
Assistant Professor : Kazuyuki Asada, Dr.

[Profile]

Keisuke Nakano received his Ph.D. from Kyoto University in 2006. He worked as a researcher at the University of Tokyo from 2003 to 2008. He has been an assistant professor from 2008 to 2012 and an associate professor from 2012 to 2018 at the University of Electro-Communications. Since 2018, he has been a professor at the Research Institute of Electrical Communication. His research interests include formal language theory, programming language theory, and functional programming. He is a member of ACM, JSSST, and IPSJ.

[Papers]

[1] Mirai Ikebuchi and Keisuke. Nakano, “On Repetitive Application of B-terms”, Third International Conference on Formal Structures for Computation and Deduction (FSCD 2018), Oxford, UK, July 2018.
[2] Yuta Takahashi and Keisuke Nakano, “Evaluating an algorithm deciding equivalence of deterministic top-down tree-to-string transducers (in Japanese)”, Computer Software, Vol. 35, No. 4, pp. 52-71, November 2018.
[3] Takeshi Tsukada, Kazuyuki Asada, and C.-H. Luke Ong, “Species, Profunctors and Taylor Expansion Weighted by SMCC —A Unified Framework for Modelling Nondeterministic, Probabilistic and Quantum Programs—”, 33rd Annual ACM/IEEE Symposium on Logic in Computer Science (LICS 2018), pp. 889-898, Oxford, UK, 2018.

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Communication Network Systems

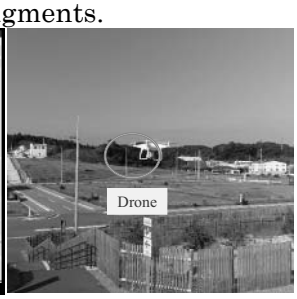
Support for Cooperation and Communication between Human and Systems

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

[Research Target and Activities]

In this year, the following studies had been done. (a) Agent-based IoT technology by which agents control several kinds of IoT devices and make the devices autonomously cooperates. (b) Agent-based network management system which supports novice network managers by automatically constructing data collection, analysis and visualization tools, and also facilitates collaboration among agents and managers. (c) Memory recall support system based on active acquisition and accumulation of memory fragments.

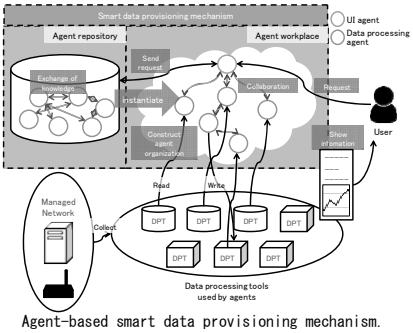
(A) Creation of Evacuation Guidance Plan



(B) Evacuation Guidance Based on Plan

(C) AIoT-Drone

Evacuation Guidance Support based on Agent-based IoT technology.



Agent-based smart data provisioning 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. Takahashi, T. Kato, T. Kinoshita, "Memory Recall Support System Based on Active Acquisition and Accumulation of Memory Fragments," Big Data and Cognitive Computing, Vol.2, No.2, 12, May 2018.
[2] G. Chakraborty, T. Kamiyama, H. Takahashi, T. Kinoshita, "An Efficient Anomaly Detection in Quasi-Periodic Time Series Data-A Case Study with ECG," Time Series Analysis and Forecasting, pp.147-157, Oct. 2018.
[3] K. Katayama, H. Takahashi, N. Yokota, K. Sugiyasu, T. Kinoshita, "Design and Implementation of Multiagent-based Evacuation Guidance Support System using UAVs," Proc. of The 9th IEEE International Conference on Awareness Science and Technology (iCAST 2018), pp.196-201, Sep. 2018.
[4] H. Matsumura, R. Fukutani, K. Sasai, G. Kitagata, T. Kinoshita, "Agent-based Smart Data Provisioning Mechanism for Supporting Network and System Administration Tasks," Proc. of 2018 IEEE 7th Global Conference on Consumer Electronics (GCCE 2018), pp.89-90, Oct. 2018.

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 have discovered practical attacks on commonly used cryptographic algorithms such as AES-GCM and elliptic curve digital signature with experimental validation (Fig. 1) and developed efficient countermeasures against proposed attack. We have also developed a new methodology for detecting malicious hardware Trojans, which are stealthily inserted to cryptographic hardware during its design/fabrication. In addition, we have developed a method for efficiently extracting hardware-intrinsic IDs from physically unclonable functions (PUFs), and developed a secure hardware authentication system based on PUF.

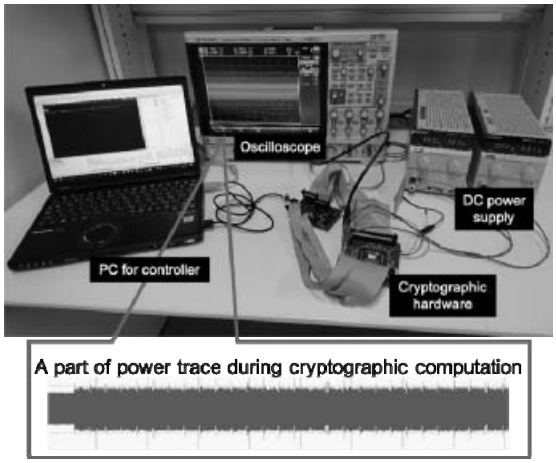


Fig. 1: Experiment for security evaluation of cryptographic hardware

[Staff]

Professor: Naofumi Homma, Ph. D
Assistant Professor: Rei Ueno, Ph. D

[Profile]

Naofumi Homma received the PhD degrees in information sciences from Tohoku University, Sendai, Japan, in 2001. 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. He received a number of awards including the IACR CHES Best Paper Award in 2014, the JSPS Prize in 2018, and the German Innovation Award in 2018.

Rei Ueno received the PhD degrees in information sciences from Tohoku University, Sendai, Japan, in 2018. Since 2018, he has been an Assistant Professor in the Research Institute of Electrical Communication, Tohoku University. He has also joined a JST PRESTO project as a researcher since 2018. He received the Kenneth C. Smith Early Career Award in Microelectronics in 2017.

[Papers]

[1] Kosuke Koiwa *et al*., "EM Security Analysis of Compact ECDSA Hardware," *Joint IEEE EMC & APEMC Symposium*, Reviewed Abstract, pp. 12, May 2018.
[2] Saki Osuka *et al*., "EM Information Security Threats Against RO-Based TRNGs: The Frequency Injection Attack Based on IEMI and EM Information Leakage," *IEEE Trans. Electromagn. Compat.*, Early Access.
[3] Akira Ito *et al*., "Characterizing Parallel Multipliers for Detecting Hardware Trojans," *Journal of Applied Logics*, Vol. 5, Issue 9, pp. 1815—1831, 2018.
[4] Manami Suzuki *et al.*, "Efficient Fuzzy Extractors Based on Ternary Debiasing Method for Biased Physically Unclonable Functions," *IEEE Trans. Circuits Syst. I, Reg. Papers*, Vol 66., Issue 2, pp. 616—629, 2019.
[5] Rei Ueno *et al*., "Tackling Biased PUFs Through Biased Masking: A Debiasing Method for Efficient Fuzzy Extractor," *IEEE Trans. Comput.*, Early Access.

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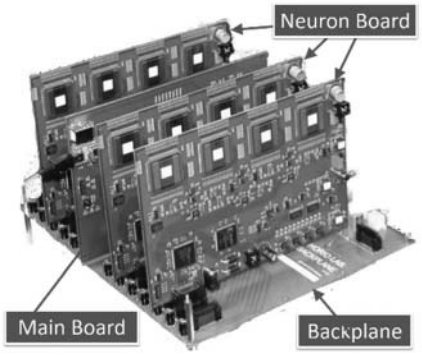
Soft Computing Integrated System

Brainmorphic Computing Hardware System

Soft Computing Integrated System Yoshihiko Horio, Professor

[Research Target and Activities]

We are working on a novel high-performance, highly-efficient, flexible, and robust brain-inspired "brainmorphic" computer hardware system. In particular, we focus on an information processing through physical complex-networked dynamical process, and its implementation as a computational hardware system using an analog VLSI as a core component. Toward the final goal, we are developing integrated circuit and device technologies suitable for the brainmorphic computer systems, such as VLSI technologies for high-dimensional chaotic networks and large-scale complex systems, VLSI circuits and architectures for ultra-low-power asynchronous neural network systems, and compact and low-power 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] Y. Horio, N. Ichinose, and M. Ogawa, "Experimental verification of quasi-periodic-orbit stabilization using a switched-capacitor chaotic neural network circuit," Nonlinear Theory and Its Applications, IEICE, vol. 9, no. 2, pp. 218-230, DOI: 10.1587/nolta.9.218, 2018.

[2] N. Ichinose, Y. Horio, and M. Ogawa, "Statistical test of quasiperiodicity in the presence of dynamical noise," Nonlinear Theory and Its Applications, IEICE, vol. 9, no. 2, pp. 231-242, DOI: 10.1587/nolta.9.231, 2018.

[3] Y. Horio, "A brainmorphic computing hardware paradigm through complex nonlinear dynamics," in Understanding Complex Systems, V. In, P. Longhini. A. Palacios, eds., Springer, 2019.

New Paradigm VLSI System Research Group

Realization of a New-Paradigm VLSI-Computing World

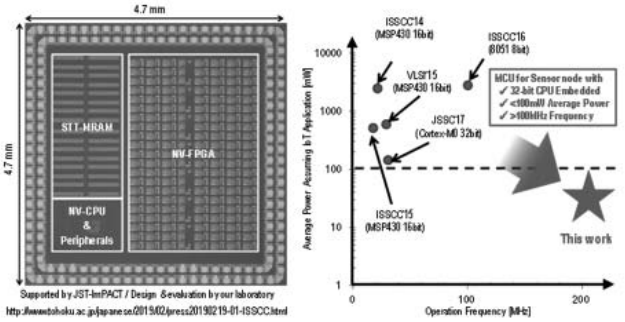


Fig. 1. MTJ-based nonvolatile microcontroller unit for IoT sensor node application achieving ultra-low power consumption of 47.14μW at a high-speed operating frequency of 200MHz.

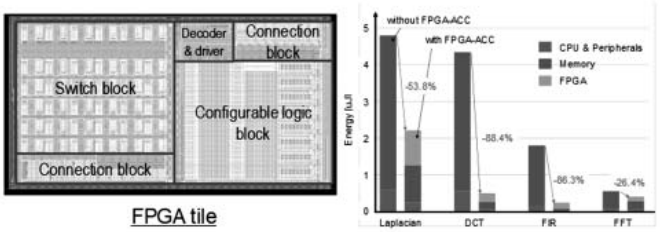


Fig. 2. Embedded nonvolatile FPGA and its impact on energy saving of nonvolatile microcontroller unit by FPGA-accelerated operation.

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 Very Large Scale Integration (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 magnetic tunnel junction (MTJ)-based nonvolatile microcontroller unit for Internet of Things (IoT) sensor node applications (Fig. 1), the MTJ-based embedded nonvolatile field programmable gate array (FPGA) that accelerates the operations of the microprocessor unit (Fig. 2), and the low-power brain-inspired vision processor using stochastic computing for object-recognition applications.

[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] M. Natsui, et al., ISSCC2019, pp. 202-203, Feb. 2019.

[2] N. Onizawa, et al., IEEE JETCAS, Vol.8, No. 3, pp. 444-453, Sep. 2018.

[3] N. Onizawa, et al., Microelectronics Journal, Vol.82, pp.46-61, Dec. 2018.

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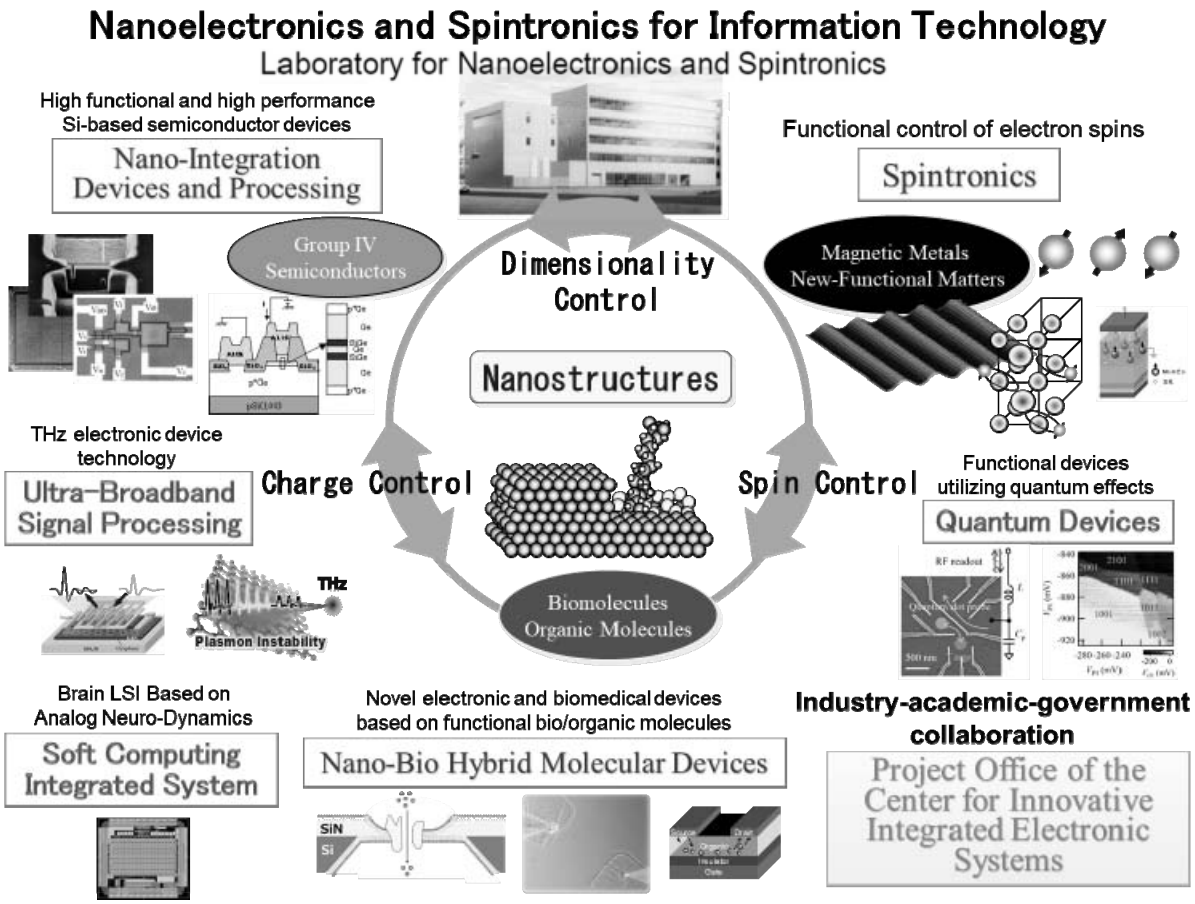
Laboratory for Nanoelectronics and Spintronics

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

The Laboratory for Nanoelectronics and Spintronics mainly consists of research groups which promote following sections: Nano-Integration Devices and Processing, 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, Soft Computing Integrated System, and Quantum Devices. 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 2018

Nano Integration

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

(1) Toward the development of quantum adiabatic computation hardware inspired by brain computation, we studied implementation using superconducting charge qubits. We successfully confirmed by numerical simulations that associative memory function can be obtained by learning.

(2) In the depth profiles of P-doped or B-doped Si epitaxial films grown by using low-energy ECR plasma CVD without substrate heating, gradual increasing tendency towards surface was observed. Additionally, improvement for electrical activation of B atoms in the heavily doped film up to above 50% has been demonstrated.

(3) Toward the development of neuromorphic computation hardware, we designed a neuron MOS analog circuit that can reproduce various neuron pulses. We confirmed by SPICE simulations that the circuit, which is composed of about 40 MOS transistors and operates in the strong inversion region, operates successfully with only about 20 μW power consumption.

(4) To study influence of the structure of neuronal circuitry and the balance of excitatory and inhibitory connections on spatiotemporal dynamics, we investigated the activity of neuronal circuitry having a modular structure. It has been clarified quantitatively that dynamical complexity is maximized when the modular network contains about 20% inhibitory connections.

● Soft Computing Integrated System (Y. Horio)

(1) We examined performance and characteristic of the chaotic reservoir network composed of chaotic neurons, which we proposed last year, through chaotic time-series predictions.

(2) For large-scale chaotic optimization hardware, we designed and fabricated a switched-current chaotic neural network integrated circuit chip with TSMC 65 nm CMOS processes.

(3) We conducted basic study on the spiking neural network hardware using spin-orbit torque neuron and STDP synaptic devices.

(4) We investigated fast hardware implementation of a random number generator based on the augmented Lorenz map for post quantum computer stream cryptography.

Spintronics and Information Technology

● Spintronics (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 electric field effect on the cone angle of easy-cone state that appears as a result of higher-order anisotropy term in CoFeB/MgO stacks by means of ferromagnetic resonance, (2) achievement of world's highest spin-orbit torque generation efficiency in high-resistivity-W/CoFeB/MgO using extended harmonic Hall technique, (3) finding a non-linear variation of domain period with

electric-field application in CoFeB/MgO stacks, which is turned out to originate from the change in exchange stiffness, (4) investigation of operation performance and reliability of analog spin-orbit torque devices that are promising for artificial-neural-network applications, (5) revealing the suitable cap-layer structure for MgO/CoFeB/Ta/CoFeB/MgO stack in terms of interfacial magnetic anisotropy and thermal stability factor, (6) world's first observation of magnetoresistance effect in antiferromagnet/nonmagnetic metallic heterostructure and clarification of underlying dominant mechanism for the magnetoresistance effect, (7) demonstration of high thermal stability factor and current-induced switching in the temperature range from -50 to 125 °C in 20-nm-wide spin-orbit torque device consisting of Co/Pt multilayer, (8) establishment of evaluation scheme for device properties of spin-orbit torque switching devices with in-plane magnetization and clarification of the dependence of device properties on the design of nanomagnet in the device, (9) demonstration of sign change of Dzyaloshinskii-Moriya interaction with ferromagnetic-layer thickness in W/(Co)FeB/MgO heterostructures.

● **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 a graphene laser-transistor featured with our original asymmetric dual-grating gates demonstrating coherent amplification of THz radiation with the maximal gain of 9% at room temperature promoted by graphene plasmon instabilities driven by dc-channel current flow.

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 introduced a uni-traveling-carrier photodiode structure into an InGaAs-channel high-electron-mobility transistor and successfully demonstrated the enormous enhancement of the gain of the frequency down-conversion from 1.5-μm optical signal to millimeter-wave signal by more than three orders of magnitude.

● **Quantum Devices (T. Otsuka)**

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 2018 are the following.

(1) We improved the operation of the local electronic probes which can directly access local electronic states in nanostructures utilizing high-frequency measurement techniques and data informatics approaches.

(2) We measured real-time changes 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 movement of a single electron.

(3) We applied the local measurement techniques to quantum bit experiments. We realized precise quantum bit operations, conversion between different qubits and multiple quantum dot operations.

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. Stable lipid bilayers in microfabricated chips having amphiphobic surfaces

   Mechanically stable lipid bilayers were formed on microfabricated silicon chips that had amphiphobic surfaces through surface modification. We also succeeded in reconstitution of cardiac hERG channel proteins into the lipid bilayers and recording their activities at the single-channel level.Reconstitution of artificial neuronal networks.
2. Reconstruction of artificial neuronal networks

   Surface engineering offers an effective solution to bridge the in vivo-in vitro gap in neuroscience. Our recent work showed that by implementing modular organization to cultured cortical neurons, their network can be tuned to generate much richer in dynamics both spatially and temporally.
3. Novel devices based on a hybrid of a phospholipid bilayer and organic semiconductor molecules

   A hybrid membrane was formed by doping a lipid bilayer with organic semiconductor molecules. Using these hybrid membranes, a photo-sensing device was formed on micro-fabricated silicon chips. It was demonstrated that the device shows high performances owing to the ultra-thin thickness of the lipid bilayer structure.

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 Soft Computing Integrated System Group), and Brain Architecture Division. 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.

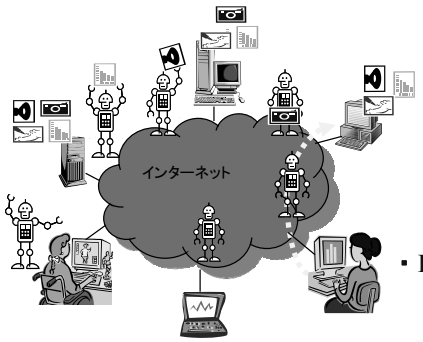
The technology developed in the Laboratory is expected to enhance the research carried out in the four Divisions of the Institute, and the research conducted in the Divisions, in turn, is expected to provide scientific basis for the information technology developed in the Laboratory.

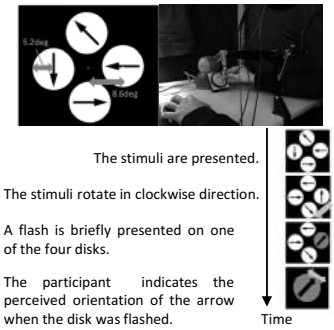
Physical and Adaptive Hardware Environment

Seamless Fusion of Real World and Multi-Modal Computing

・Brain-Like Computing

(Brain Architecture)





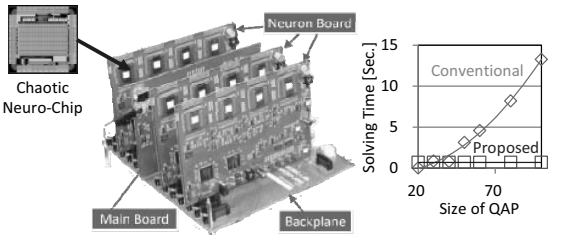
・ Real-World Dynamical Intelligence

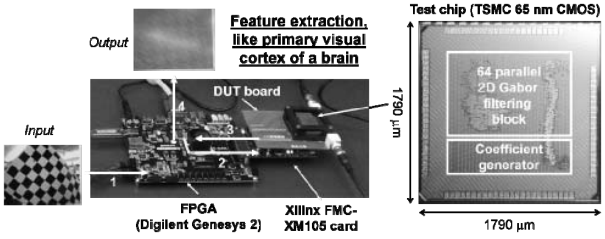
(Real-World Computing)

・ 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]

The goal of this facility is to develop fundamental technologies and their applications that will lead the world to the next-generation information system that seamlessly integrates the cyber-physical world and the ever-changing real world. In order to realize this goal, each laboratory participating in this facility has set the following individual goals and promotes research activities as follows:

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]

Aiming at the seamless integration of the cyber-physical world and the real world, which is the goal of Laboratory of Brainware Systems, the following research results were obtained. In particular, the following research results in fiscal year 2018 are an important step towards the goal as:

--Real-World Computing Section gets the award by presenting "Decentralized Control Law of Six-Leg Robot Capable of Generating Walking Motion According to Leg Disconnection Situation" reported in 30th Autonomous Distributed System Symposium.
http://www.riec.tohoku.ac.jp/ja/information/award/2019/02/post-19266/

--New Paradigm VLSI System Section achieves "Below 50μW Operation at 200MHz in a Nonvolatile Microcontroller Unit for Sensor-Node Applications" reported in ISSCC 2019.
http://www.tohoku.ac.jp/japanese/2019/02/press20190219-01-ISSCC.html

--Recognition and Learning Systems Section demonstrates "Spatial representations of the viewer's surroundings" reported in Scientific Reports.
http://www.tohoku.ac.jp/japanese/2018/05/press20180509-01-ushiromomirume.html

--Soft Computing Integrated System Section develops "Neuron and Synapse-Mimetic Spintronics Devices" reported in Advanced Materials.
http://www.tohoku.ac.jp/japanese/2019/04/press-20190415-AdvMater.html

The more detailed research results of each section (laboratory) are shown as follows:

Real-World Computing Section:
(refer to Real-World Computing Laboratory in Human Information Systems Division)

New Paradigm VLSI System Section:
(refer to New Paradigm VLSI System Laboratory in Systems & Software Division)

Recognition and Learning Systems Section:
(refer to Visual Cognition and Systems Laboratory in Human Information Systems Division)
(refer to Advanced Acoustic Information Systems Laboratory in Human Information Systems Division)

Soft Computing Integrated System Section:
(refer to Soft Computing Integrated System Laboratory in Systems & Software Division)

Recognition and learning systems laboratory

Understanding the human recognition and learning systems

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

[Research Target and Activities]

To create computational models of the process in the human brain that 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.

In this year, first, we investigated a model of motion in depth based on interocular velocity difference (IOVD). Perception of motion in depth is important to humans, who live in the three dimensional world. One wants to avoid being hit or to catch objects approaching. We built a model of direction perception of motion in depth to investigate how IOVD cue can be used for motion in depth perception. IOVD is one of well-known three cues for motion in depth, with disparity change in time and size change. We found that the IOVD model can explain many of psychophysical results such as discrimination threshold of motion in depth direction, nonlinear results of motion in depth direction, temporal properties of rotation in depth and so on. These results suggest that IOVD is an important cue for visual processing of motion in depth. Second, we investigated the mechanism of auditory selective attention, especially the dependence of the spatial tuning of auditory selective attention. The results of speech intelligibility test under noisy environment revealed that the attention spotlight is modulated by the direction of the attention.

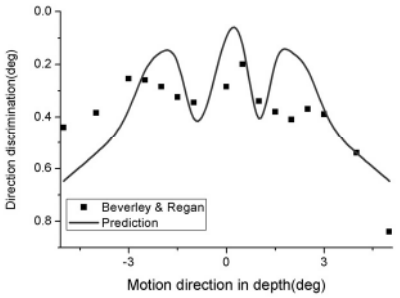


Figure. Prediction (red line) of direction discrimination in motion in depth measured by human psychophysical experiment (black dots).

[Staff]

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

[Papers]

1. R. Teraoka, S. Sakamoto, Z. Cui, Y. Suzuki, S. Shioiri: "Influence of auditory selective attention on word intelligibility," Proc. 65th Open Seminar on Acoustics, 307-310, 2018.
2. N. Onizawa, S. Koshita, S. Sakamoto, M. Kawamata, T. Hanyu: "An Area/Power-Aware 32-channel compressive gammachirp filterbank chip based on hybrid stochastic/binary computation," Nonlinear Theory and Its Applications, IEICE, E9-N(4), 406-422, 2018.
3. S. Shioiri, K. Hashimoto, K. Matsumiya, I. Kuriki, S. He: "Extracting the orientation of rotating objects without object identification: Object orientation induction," Journal of vision 18 (9), 17-17, 2018.
4. S. Shioiri, M. Kobayashi, K. Matsumiya, I. Kuriki: "Spatial representations of the viewer's surroundings," Scientific reports 8 (1), 7171, 2018.
5. D. Kang, YW. Sung, S. Shioiri: "Estimation of physiological sources of nonlinearity in blood oxygenation level-dependent contrast signals," Magnetic resonance imaging 46, 121-129, 2018.
6. M. Emoto, Y. Fang, S. Shioiri: "Viewers' Susceptibility to Image Blurs in Watching Ultra-high-definition TV Correlates with Their Dynamic Visual Acuity," ITE Transactions on Media Technology and Applications 7 (2), 103-110, 2019.

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. Last 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 one group, "Wireless ICT platform project". Presently, following project is carried out in this group.

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

From 2017, 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 multi-band/real-time spectrum monitor which can detect several-tenths μs order burst signal/noise.

[Staff]

Director: Noriharu Suematsu, Professor

Industry-Academia-Government-Collaboration Research and Development Division (Wireless ICT platform project)

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 Industry-Academia-Government-Collaboration Research and Development Division, Wireless ICT Platform Project

Dependable Air

Noriharu Suematsu, Professor (Project Leader)
Suguru Kameda, Associate Professor
Mizuki Motoyoshi, Assistant Professor
Koji Okazaki, Visiting Professor

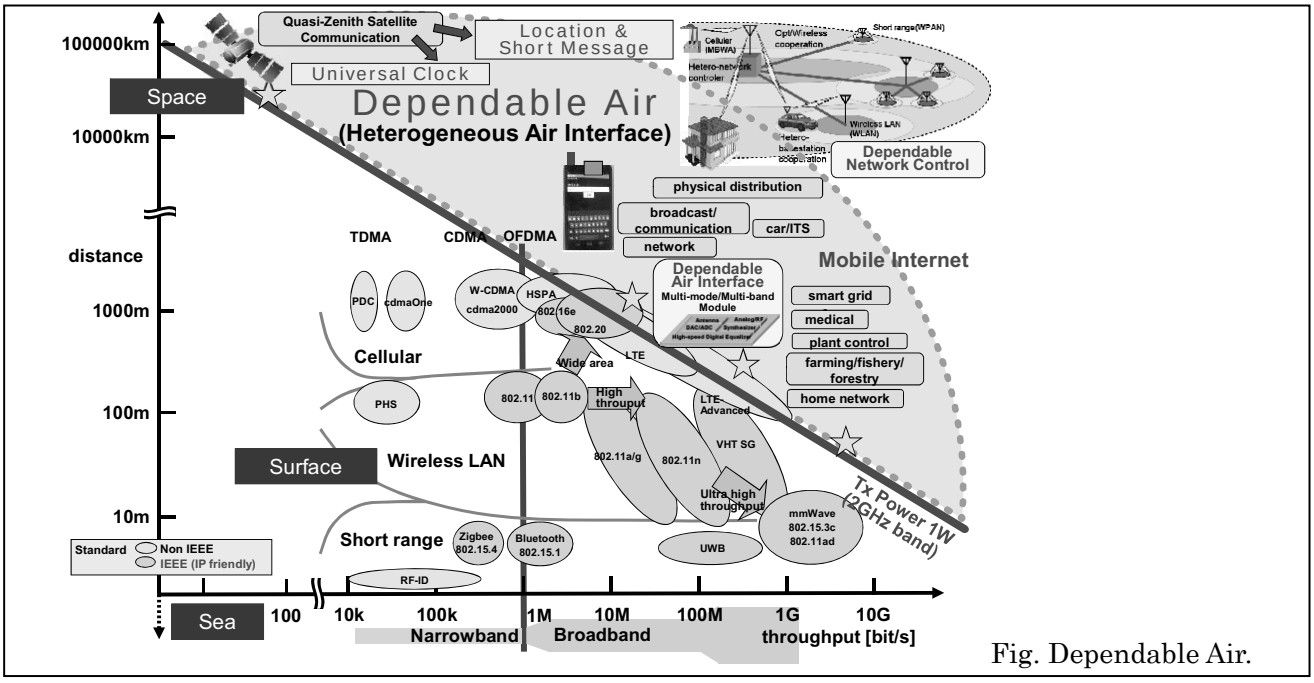


Fig. Dependable Air.

[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. 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 from 2017.

[Staff]

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

[Papers]

[1] N. Yoshino, K. Norishima, M. Motoyoshi, S. Kameda, N. Suematsu, N. Suematsu, "28 GHz-Band Direct RF Undersampling S/H CMOS IC with 40 dB SNR," 2018 IEEE International Symposium on Radio-Frequency Integration Technology (RFIT2018), 15-17 Aug. 2018

[2] T. Furuichi, M. Motoyoshi, S. Kameda, N. Suematsu, "A study on Direct RF Undersampling Receiver Configuration considering Timing Skew Spurs using Time-Interleaved ADC," 2018 Asia Pacific Microwave Conference (APMC2018), Nov. 2018

Interdisciplinary Collaboration Research Division

Research project of human value estimation of multimodal information based on informatics paradigm to manage both quality

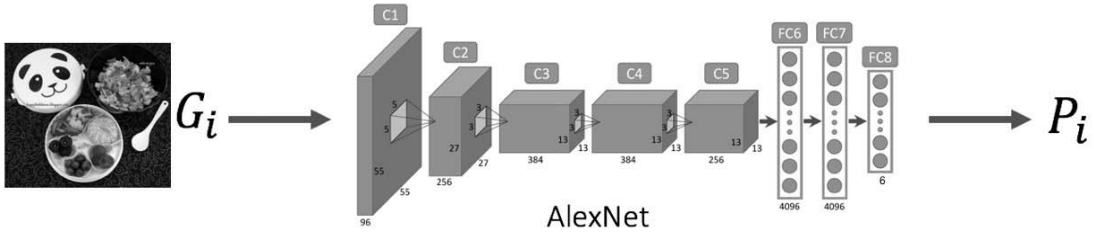


Fig. 1 Estimation of human higher order Judgments with Convolutional Neural Networks. Prediction for each image, P*i*, based on training with input image with ground truth, G*i*.

Satoshi Shioiri, Dr. Professor
Nobuyuki Sakai, Dr. Professor

[Research Target and Activities]

One of our major research activities is investigation of the usage of Convolution Neural Networks as decision support system for high level human judgments such as preference of images (Fig. 1), using a lunchbox dataset, containing 760 images. To compensate the small size of the dataset, we fine-tuned several layers of a trained CNN for object recognition (AlexNet). The fine tuned network succeeded to predict high-level human judgments with dataset size of less than 1000 with a considerable accuracy.

[Staff]

Professor : Satoshi Shioiri, Dr.
Professor : Nobuyuki Sakai, Dr.
Assistant Professor : Kosuke Yamamoto

[Profile]

Satoshi SHIOIRI Professor Shioiri graduated Tokyo Institute of Technology and received Dr. Eng in 1986. In 2005, he joined Tohoku University and he has been a professor of Research Institute of Electrical Communication of Tohoku University since then.

Nobuyuki Sakai graduated from Graduate School of Human Sciences, Osaka University in 1998. Then he worked at Hiroshima Shudo University and National Institute of Advanced and Industrial Science and Technology (AIST) , Kobe Shoin Women's University. He, then, moved to Sendai in October 2011, and he is a professor of Graduate School of Arts and Letters of Tohoku University now.

[Papers]

[1] Shioiri, S., Kobayashi, M., Matsumiya, K. & Kuriki, I.Spatial representations of the viewer's surroundings.Scientific reports 8, 7171, doi:10.1038/s41598-018-25433-5 (2018).
[2] Hao Wang, Kazuya Matsubara, Yuji Wada, Chia-huei Tseng, Kazumichi Matsumiya, Ichiro Kuriki and Satoshi Shioiri,The Evaluation of Images based on Human Preference with Convolutional Neural Networks, APCV 2018.
[3] Takuya Onuma, Hiroaki Maruyama, and Nobuyuki Sakai Enhancement of Saltiness Perception by Monosodium Glutamate Taste and Soy Sauce Odor: A Near-Infrared Spectroscopy Study. Chemical Senses, Volume 43, Issue 3, Pages 151–167 (2018)

Exploratory Research Division

Interactive Drone Content for Entertainment / Wildlife Symbiosis

Yoshifumi KITAMURA, Professor

[Research Target and Activities]

This project aims to develop core technologies of interactive drone content for real industrial use including entertainment and wildlife symbiosis, through close industry/academia/government cooperation. It is expected to support continuous development of drone technologies through this innovation, and produce new industry and services in response to societal needs.
The followings are current research projects:
(1) Development of intuitive user interface for a drone pilot
(2) Development of crow-type-drone to communicate with crows.
(3) Techniques for video sharing and distribution for enhancing entertainment of drone race.

[Staff]

Professor: Yoshifumi Kitamura, Dr.

[Profile]

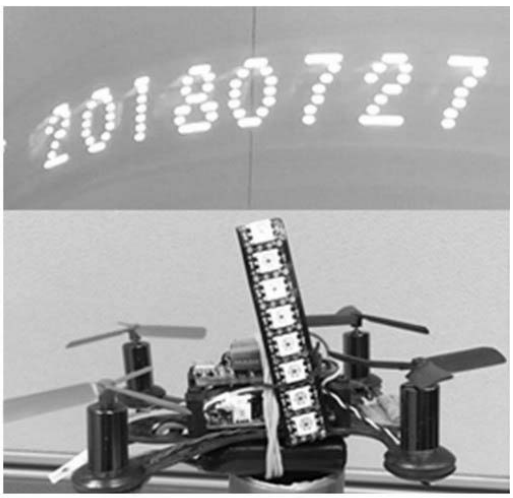
Yoshifumi Kitamura: Since 2010, he has been Professor in the Research Institute of Electrical Communication, Tohoku University. Prior to arriving at Tohoku, he was an Associate Professor at Graduate School of Engineering, and Graduate School of Information Science and Technology, Osaka University. While 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] Koh Sueda, Takashi Kitada, Yushin Suzuki, and Taiki Wada: Research and Development of Augmented FPV Drone Racing System. In SIGGRAPH Asia 2018 Posters (SA '18). ACM, New York, NY, USA, Article 9, 2 pages, 2018. DOI: https://doi.org/10.1145/3283289.3283322

[2] Koh SUEDA et al: “Introduction Of Augmented FPV Drone Racing”, In SIGGRAPH Asia 2018 Birds of a Feather, 2018 https://sa2018.siggraph.org/en/attendees/birds-of-a-feather/session/204

A prototype of Stuffed crow robot



A drone race machine with LED array

IT21 Center

Exploratory Research Division

Wireless IoT Technology for a Safe & Secure Medication Management System

Safe & Secure Medication Management System using Wireless IoT Technology

Suguru Kameda, Associate Professor (Project Leader)
Noriharu Suematsu, Professor
Takahiro Hanyu, Professor
Kazushi Ishiyama, Professor
Naofumi Homma, Professor
Qiand Chen, Professor
Mizuki Motoyoshi, Assistant Professor

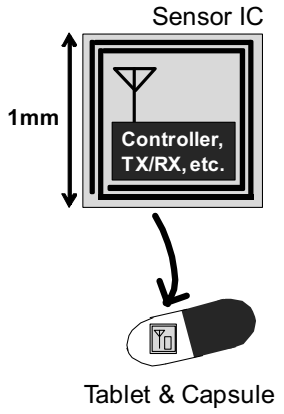


Fig.1 Battery-less tablet-pasting-type sensor

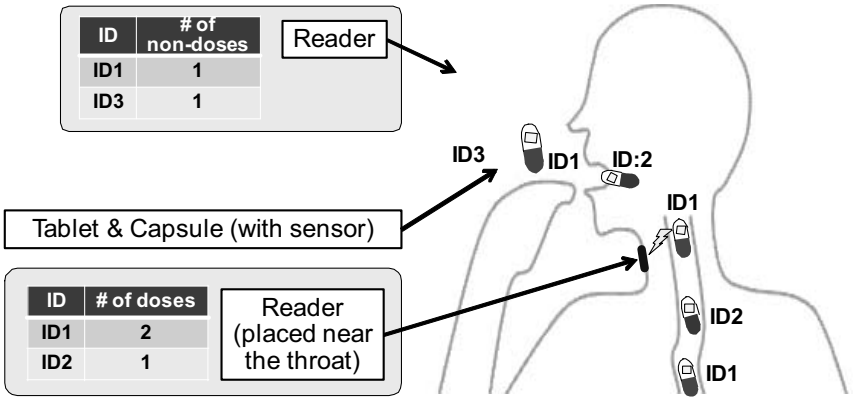


Fig.2 Safe medication management system

[Research Target and Activities]

Medical costs that continue to increase with progress in aging society and medical advances are serious social problems on the worldwide scale. In order to reduce medical expenses, it is indispensable to construct a medication management system that enables inventory control and confirmation of ingestion.

This division conducts exploratory research on establishing a safe medication management system using wireless IoT technology. The goal of this research is the realization and practical implementation of system construction that allows patients to take medication management just by taking tablet-type medicine. In this research, we are now studying for the battery-less tablet-pasting-type sensor by applying wireless IoT technology.

In this year, we developed low power oscillator for wireless transceiver of battery-less sensor node. The fabricated IC using 65nm bulk CMOS process performs 57.4 GHz with 130 μW power consumption. The FoM is 10dB higher than those of previously reported.

[Papers]

[1] M. Motoyoshi, S. Kameda, N. Suematsu, "57 GHz 130 μW CMOS Millimeter-wave oscillator for ultra-low power sensor node," 11th Global Symposium on Millimeter-Waves, May 2018

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: Kazushi Ishiyama, 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.

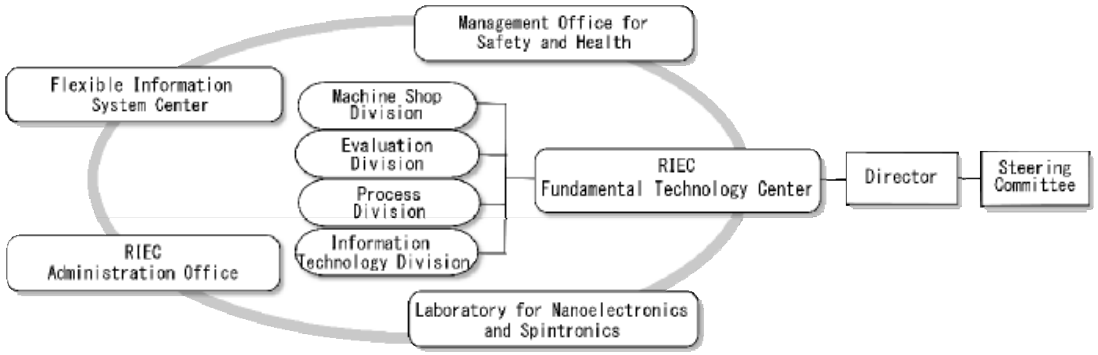
[Staff]

(1) Steering Committee
Professor: Tetsuo Kinoshita, Dr., Yôiti Suzuki, Dr., 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 the Fundamental Technology Center

[Research Target and Activities]

The Fundamental Technology Center provides a wide range of technical support for research and development through four divisions: Machine Shop Division, Evaluation Division, Process Division, and Information Technology Division. The following is a summary of the activities of the divisions of the Fundamental Technology Center for the current year.

1. Machine Shop Division

Following requests from researchers, the Machine Shop Division supplied 120 machining products. About 15% of the requests were from outside the institute.

2. Evaluation Division

An organization and 22 laboratories utilized the evaluation and measurement apparatuses for shared usage (the utilization time was 7385 hours). Two glass processing products were supplied. Technical assistance was provided on the use of liquid helium and 1011 liters of liquid nitrogen were supplied. In cooperation with the administration and the management offices for safety and health, this division also engaged in safety maintenance of the institute.

3. Process Division

In cooperation with the technical office, a section of the Laboratory for Nanoelectronics and Spintronics, 141 Electron-beam lithographic products and 25 photomasks were supplied. Technical supports were provided for operating the clean room of the 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 the Flexible Information System Center. This division also engaged in the contracting aspects of collaborative research based on intellectual property rights and gave advice to researchers who tried to apply for the grant of patents.

[Staff]

Director (Professor): Shigeo SATO.

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, 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 research group investigates representation of space in the brain, which expresses the outside space based on multiple sensory information. We hypothesize that space attention in the multi-sensory representation is the process for selecting action. We started to investigate interaction between visual and auditory attention. Our proposal of a project, 'control of audiovisual attention by spontaneous attention,' has been accepted for Kaken A, this year.

[Yotta Informatics Research Group]

The amount of information is rapidly increasing, which is projected to reach to the amount of one yotta bytes, one trillion times of one Tera-bytes, or 10 to 24th bytes. The information is too large to coop with it by the conventional ICT technology. Therefore, essential paradigm shift for the information processing is indispensable. In this group, we aim at the new informatics, which can manage the “quality” of information as well as the information “amount”. In 2018, our group supported the activity of Advanced Institute of Yotta informatics for interdisciplinary collaboration projects and an international symposium of Yotta projects.

[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 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. In this year, we discussed a basic strategy to propel collaborative researches on brainmorphic hardware and biotronics from broad perspective that includes brain science, spintronics, analog/digital integrated circuits, cultured neurocyte, and nonlinear complex dynamics.

[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, we have investigated the novel wireless IoT communication system between high speed/mobility wireless sensor nodes and access points.

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 ：Tetsuo Endoh (Professor and Director of CIES)

・Number of Researchers：25 (including 19 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 2017/12/1～2019/3/31)" in ImPACT program (Program Manager: Prof. Masashi Sahashi) of CSTI

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

＜Major Achievements in 2018＞

(1) We have developed an MTJ-based nonvolatile MCU with 1.5 million MTJ devices for operating by energy harvesting and succeeded in demonstrating an operation with an average power consumption of 47.14 μW at a maximum operating frequency of 200 MHz. This result indicates that it can simultaneously achieve an improvement in performance by more than two times and reduction in power consumption of more than two digits compared to previous MCUs with embedded nonvolatile memories. It solves the trade-off between performance and power consumption of existing silicon technology. (2) We have developed spintronics device using both spin orbit torque (SOT) and spin transfer torque (STT), and demonstrated magnetization reversal by the world's fastest 200 ps pulse under zero magnetic field. (3) We have succeeded in achieving the spin-orbit torque efficiency (effective spin-hole angle) of 1.2, which is the world's highest value, in the W/CoFeB/MgO stack structure using high resistivity W. (4) We designed an SOT-MRAM as well as establishing the device characteristic simulation environment and the design environment required for the SOT-MRAM design and layout. (5) Using the process line for 300 mm wafer, we have developed the Via planarization process under the SOT device, SOT device etching process and SOT device lower electrode formation process which are the key processes of SOT-MRAM manufacture.

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]
絣Since 2012, we have been promoting 12 disaster-resilient ICT projects supported by the Ministry of Internal Affairs and Communications. In 2018, 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 carried out enlightenment to the local governments with "Disaster-resistant ICT introduction guidelines" revised by the Disaster Resistant ICT Research Council. 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 2018.

Fig.1 Research Organization of Electrical Communication.

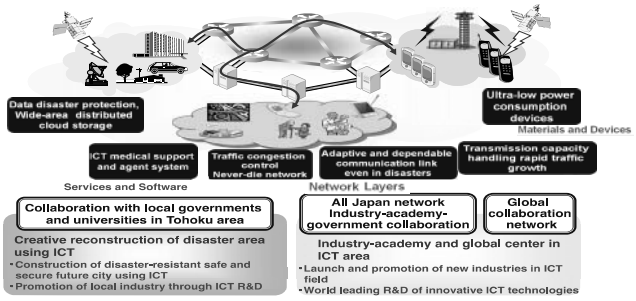


Fig.2 Overview of ICT Reconstruction Project.

[Staff]
Prof. Nei Kato (Executive Director)
Prof. Masayuki Kawamata (Vice Executive Director)
Specially Appointed Prof. Hiroyuki Ogawa (Vice Executive Director)
Specially Appointed Prof. Katsumi Iwatsuki (Research Administrator)
Mr. Masato Kaneko (Office Manager)
Mr. Syuichi Terashima (Manager)
Ms. Izumi Ishikawa (Secretary)
[Papers]
[1] Tohn Furutani, et al., "A Novel Information Diffusing Method With Virtual Cells Based Wi-Fi Direct In Disaster Area Networks," IEEE WCNC 2018, Barcelona Spain, Apr. 2018.
[2] K. Kasai, et al., "Backward-Rayleigh-Scattering Suppressed 160 Gbit/s 256 QAM Injection-Locked Bidirectional Coherent Transmission for Next Generation Mobile Fronthaul," ECOC 2018, Th2.71, September 2018.
[3] M. Suzuki, et al., "Introduction of 2D Diffraction Grating into Grating-Gate Plasmonic THz Detector for Controling Its Polarization Characteristics," AWAD 2018, Kitakyushu, Japan, Jul. 2-4, 2018

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: 81 (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 FY2018＞

CIES has managed the “CIES consortium” which consists of seven industry–academic collaborations, major national projects (JST-ACCEL, JST-OPERA, CAO-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. We have proposed a new method of MTJ and succeeded in demonstrating operation with one-digit nanometer size which is the smallest in the world. Also, in collaboration with CIES consortium companies, we developed MTJ manufacturing process for increasing the

memory capacity. Based on the results of collaborative research, MTJ characterization solution was commercialized and there was progress made to sell to the world. In FY2018, Tohoku University's proposal “R&D of ultralow power IoT devices and its technical platform with MTJ/CMOS Hybrid technologies for Society 5.0” was accepted as a Cabinet Office SIP 2nd Phase “Physical space digital processing platform”, and this new national project was launched. It is expected to be applied to the IoT/AI system where ultralow power consumption is required. In addition, a CIES branch in the Research Center for Rare Metal Green Innovation was established, and an industry-academic collaboration on next-generation power devices in JST OPERA project has significantly developed. It is expected to be applied in IoT / AI systems that require ultra-low power consumption. 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.

Center for Spintronics Research Network (CSRN)

＜Overview＞

Establishment: April 1, 2016

Organization: Director: Koki Takanashi (Director, Professor, IMR)

Number of academic members: 64 (including 5 full-time members and the other concurrent members from Grad. School of Science, Grad. School of Engineering, IMR, RIEC, IMRAM, AIMR, CSIS, CIES, and FRIS, Tohoku University and NIMS)

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 FY2018＞

・Cooperative Research Project

We adopt 54 cooperative research projects to promote collaborations with other spintronics researchers. The collaborators belong 39 institutions in Japan and 23 overseas institutions (in 11 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 second Workshop was held in Singapore on February 22, 2019. For promoting exchange and fostering human resources of spintronics researchers, CSRN jointly hosted international conferences, workshops, and schools (15 meetings in total).

Advanced Institute for Yotta Informatics

＜About the Center＞

Establishment：April 1, 2018

Based on research activities as a Program for Key Interdisciplinary Research of Tohoku University from 2015 to 2017, Yotta Informatics Research Center is granted by MEXT in 2018.

Organization：Director: Satoshi Shioiri (Director, Professor, RIEC)

Number of members: 34 (RIEC, Graduate School of Engineering, AIMR, Graduate School of Arts & Letters, Graduate School of Information Sciences, Graduate School of Economics and Management, Graduate School of Biomedical Engineering, Graduate School of Education, Graduate School of Life Sciences)

Research Target：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 sciences.

Research Activities：The amount of information is rapidly increasing, which is projected to reach to the amount of one yotta (10^{24}) 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 institute, 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 sciences 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 Achievements in 2018＞

1. We have started 9 interdisciplinary projects that lead the new information science, which can manage the quality of information as well as the information amount and select important information appropriately. We published 50 papers and 55 presentations (including 25 invited talks), and obtained 5 new external grants in this year.
2. We organized an international symposium “Symposium of Yotta Informatics – Research Platform for Yotta-Scale Data Science 2019” and co-organized a RIEC international symposium “Tohoku U - NTU Symposium: When AI Meets Human Science," and invited many researchers from inside and outside of Japan.
3. Our application to RIEC Nation-wide Cooperative Research Projects (International Cooperative Research Project) was adopted, and we have started cooperative research with an overseas research institute. To establish an open innovation platform for information-quality informatics studies, we have started an project with an industrial company, and started a new interdisciplinary project with the IT-21 Center in collaboration with Division for Interdisciplinary Advanced Research and Education.

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

＜Overview＞

Establishment: October, 2013

Organization; Program manager: Hirotsugu Takizawa (Executive Vice President for Education and Student Support)
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 FY2018＞

In FY2018, 4 new students joined the program and 62 students in total learned the fundamental and specialized subjects and joined long-term internship at domestic corporations and foreign institutions.

The 4th Symposium between the MD program and Ambitious Leaders program (Hokkaido University) was held in Sapporo during May 18-20, 2018. A variety of programs, such as laboratory tour, facilitation lectures, poster sessions and workshops, were carried out during the symposium for deepening mutual understanding and exchanges between students of both programs.

Graduate Program in Spintronics (GP-Spin)

＜Overview＞

Establishment: April 1, 2015

Organization: Program manager: Hirotsugu Takizawa (Executive Vice President for Education and Student Support)
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 FY2018＞

In FY2018, 14 invited researchers gave lectures at the GP-Spin Seminar during their stays in Tohoku University.

The Joint Seminar organized by GP-Spin students was held during March 1-2, 2019 at Tohoku University. World-leading 3 researchers in spintronics invited from Johannes Gutenberg University Mainz, University of Exeter and the City University of New York gave special lecturers. Students and young researchers from Johannes Gutenberg University, University of Lorraine, and Tohoku University also gave exciting talks and poster presentations on their new research results.

The Students Workshops were held at Tohoku University on August 22, 2018 and on March 11, 2019 for improving presentation skills of GP-Spin students.

Center for Science and Innovation in Spintronics (CSIS)

＜Overview＞

Establishment: January 30, 2018

Organization: Director: Yoshio Hirayama (Professor, Graduate School of Science)
Number of academic members: 34 (concurrent members from Grad. School of Science, Grad. School of Engineering, IMR, RIEC, IMRAM, AIMR, FRIS, CSIS, CIES, and CSRN, Tohoku University)

Mission: Creation of world-leading research center pioneering in so-called “Spin-Centered Science” by strategic consolidation of excellent researchers from foreign leading universities in fundamental and applied fields.

Research activities:
Spin-centered fundamental science, advanced spintronic materials, spintronic devices, and integration technology of spintronic devices.

＜Major activities in FY2018＞

・Cooperative Research Project

We adopt 13 cooperative research projects to promote collaborations beyond the past framework at Tohoku University. These proposals have potentials to lead to high-quality achievements and international joint papers.

・Joint Research Laboratory

Joint Research Laboratory was established at Tsinghua University in China to promote collaborative research on “Spin detection and manipulation in topological insulator based heterostructures.”

・International Academic Meetings

The international workshops were held to promote academic exchange between CSIS and foreign leading universities; Tsinghua University (July 2018 in Sendai) and University College London (October 2018 in London). The 2nd Symposium for World-Leading Research Centers –Materials Science and Spintronics- was held on February 16-18, 2019 at Sendai International Center. More than 250 participants including 24 foreigners from 6 countries attended the symposium.

Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan
WISE Program (Doctoral Program for World-leading Innovative & Smart Education)
Advanced Graduate Program for AI Electronics

＜About the Center＞

Establishment : Adopted October, 2018.
It has been adopted by the WISE Program (Doctoral Program for World-leading Innovative & Smart Education) of MEXT. This program is a new education program that starts from FY 2018.

Organization : Chief executive: Hideo Ohno (President of Tohoku University)
Program leader: Masahiro Yamaguchi (Vise-President of Tohoku University (Education Reform / International Strategy))
Program coordinator: Toshiro Kaneko (School of engineering, Professor)
Program manager: Approximately 60 people (including managers and a coordinator)

Target of Program : In this Graduate School Program, we will foster world-class talented doctors who can make an innovation continuously through the learning of “an practical ability”, “solving of social problems”, “creation of novel value”, and “an ability that can see real space and cyber space in Society 5.0 with wide perspectives”.

＜Major Achievements in 2018＞

Recruitment and selection of first-term students were conducted. 36 program students (15 M1 students, 9 M2 students, and 12 D1 students) for FY 2019 were determined.

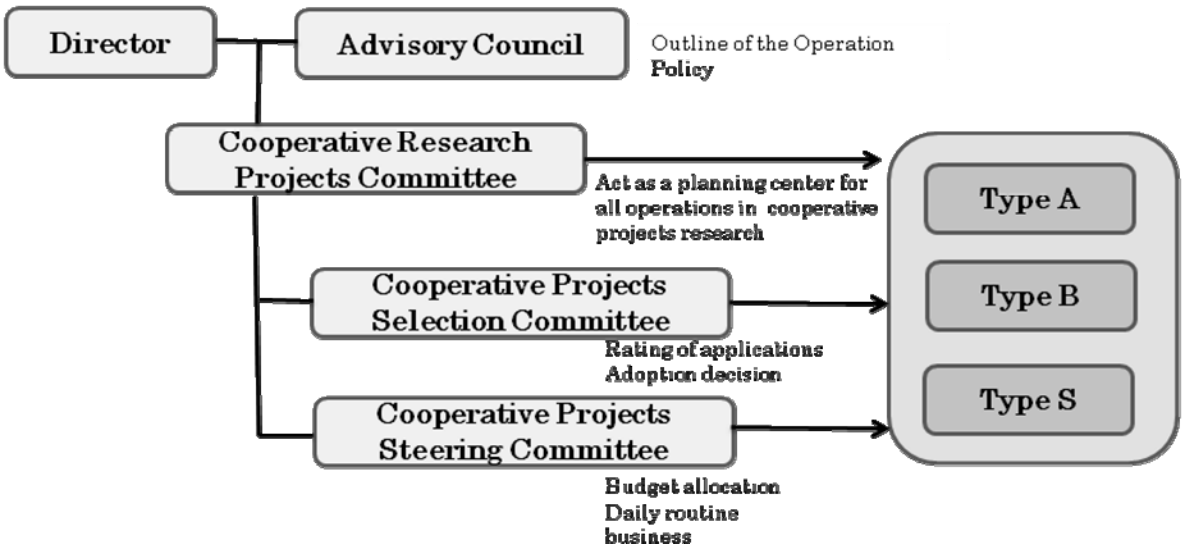
4. Nation-wide Cooperative Research Projects

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 2018

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
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	Effect of interactive confectionary feed device to support intellectual creation activities	**UEOKA Ryoko** Faculty of Design, Kyushu University	**TAKASHIMA Kazuki**
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**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
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	Design and Globalization of Dissipative Infrastructure	KASHIWAZAKI Hiroki Cybermedia Center, Osaka University	KITAGATA Gen
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/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/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

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
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/A07	Study on single-crystal graphene devices	**NAGASE Masao** Graduate School of Technology, Industrial and Social Sciences 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**
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	Evaluating visual contents based on collaborative EEG signals from multiple subjects	**TOUYAMA Hideaki** Faculty of Engineering, Toyama Prefectural University	**KITAMURA Yoshifumi**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H29/A16	Cultural and individual differences in color lexicon	**TOKUNAGA Rumi** College of Liberal Arts and Sciences, Chiba University	**KURIKI Ichiro**
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**
H29/A19	Gaze Visualization in Cooperative Work	**KIYOKAWA Kiyoshi** Graduate School of Information Science, Nara institute of science and technology	**KITAMURA Yoshifumi**
H29/A20	Development of the object based audio by sound field rendering with surrounding loudspeaker array	**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 Comprehensive Informatics, Shizuoka Institute of Science and Technology	**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** Department of Psychology, National Taiwan University	**TSENG Chia-Huei**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
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	The source-direction dependency of pinna shape and acoustic transfer function	**ITO Masashi** Faculty of Engineering, Tohoku Institute of Technology	**SAKAMOTO Shuichi**
H29/A29	Research on the development of a new generation IoT platform	**ZABIR Salahuddin Muhammad Salim** Department of Creative Engineering, National Institute of Technology, Tsuruoka College	**KINOSHITA Tetsuo**
H29/A30	Study on Device Cooperative System Supporting User Behavior Synchronization	**YAMAZAKI Tatsuya** Faculty of Engineering, Niigata University	**TAKAHASHI Hideyuki**
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**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H30/A01	Advaced Devices Researches by Using Spatio-Temporal X-ray spectroscopy	**FUKIDOME Hirokazu** Research Institute of Electrical Communication, Tohoku University	**FUKIDOME Hirokazu**
H30/A02	Creation of Bio-Medical Devices Using Gas-Liquid Interfacial Plasmas	**KANEKO Toshiro** Graduate School of Engineering, Tohoku University	**HIRANO Ayumi**
H30/A03	Quantum devices based on atomic layers	**MASUBUCHI Satoru** Institute of Industrial Science, Univeristy of Tokyo	**OTSUKA Tomohiro**
H30/A04	Japan-Russia International collaborative research on gated GaAs structures with an array of self-assembled Sn-nanothreads and their terahertz applications	**DMITRY Ponomarev** Institute of ultra high frequency semiconductor electronics of Russian academy of sciences, Laboratory of high-power microwave and mm-wave applications	**OTSUJI Taiichi**
H30/A05	Development of vibrational spectroscopy having high temporal and spatial resolution and its application to devices	**UEHARA Yoichi** Research Institute of Electrical Communication, Tohoku University	**UEHARA Yoichi**
H30/A06	Development of general control techniques of quantum systems	**FUKUHARA Takeshi** Center for Emergent Matter Science, RIKEN	**OTSUKA Tomohiro**
H30/A07	Control of spin state in semiconductor using photon-spin conversion	**ISHIHARA Jun** Department of Applied Physics, Faculty of Science, Tokyo University of Science	**KANAI Shun**
H30/A08	Nanoscale optical measurement and ultimate photoelectronic control of carbon nanomaterials	**KATANO Satoshi** Research Institute of Electrical Communication, Tohoku University	**KATANO Satoshi**
H30/A09	Informatics approaches in quantum devices	**SHIGA Motoki** Faculty of Engineering, Gifu University	**OTSUKA Tomohiro**
H30/A10	Development of Low-Energy Plasma Process for High-Performance Group-IV Semiconductor Quantum Nanodevices	**SAKURABA Masao** Research Institute of Electrical Communication, Tohoku University	**SAKURABA Masao**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H30/A11	Energy Harvest applied Active Reflectarray for Mobile IoT search range expansion	**MARUYAMA Tamami** Department of Production Systems Engineering, National Institute of Technology, Hakodate College	**SUEMATSU Noriharu**
H30/A12	A Study of delay-sensitive access network configuration using widely frequency selectable optoelectronics devices	**YOSHIMOTO Naoto** Faculty of Science and Technology, Chitose Institute of Science and Technology	**OTSUJI Taiichi**
H30/A13	Single and coupled hard-type oscillators using resonant tunneling diodes and their application to THz signal processing	**MAEZAWA Koichi** Graduate School of Science and Engineering, University of Toyama	**OTSUJI Taiichi**
H30/A14	Loss Analysis of High Efficient Contactless Power Transmission	**INAMORI Mamiko** Department of Electrical and Electronic Engineering, Tokai University	**KAMEDA Suguru**
H30/A15	Study on method for modulating emotional experience by choice	**SAKAI Nobuyuki** Graduate School of Arts Letters, Tohoku University	**SHIOIRI Satoshi**
H30/A16	Modulation of peripersonal space representation by self-motion information	**TERAMOTO Wataru** Graduate School of Social and Cultural Sciences, Kumamoto University	**SAKAMOTO Shuichi**
H30/A17	Study of difference between monaural listening and binaural listening on sound space perception	**MORIKAWA Daisuke** Faculty of Engineering, Toyama Prefectural University	**SAKAMOTO Shuichi**
H30/A18	Emergency vital measurement using flexible silk-fiber electrode under electromagnetic environment	**TORIMITSU Keiichi** Research Organization of Electrical Communication, Tohoku University	**SUEMATSU Noriharu**
H30/A19	Research on gravimetric technology for monitoring volcanic activities using an optical fiber network	**ARAYA Akito** Earthquake Research Institute, The University of Tokyo	**YOSHIDA Masato**
H30/A20	Hardware Technology for Brain Computing and its Applications	**SATO Shigeo** Research Institute of Electrical Communication, Tohoku University	**SATO Shigeo**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H30/A21	Effect of multi-sensory information on the sense of presence and verisimilitude on audio-visual information	**OHTANI Tomoko** Art Media Center, Tokyo University of the Arts	**Jorge Alberto Trevino Lopez**
H30/A22	Development of Tsunami Evacuation Guidance Support System used by IoT Technology	**SUGIYASU Kazuya** International Research Institute of Disaster Science, Tohoku University	**TAKAHASHI Hideyuki**
H30/A23	Improving sound source localization with measurement in real environments	**KOMATANI Kazunori** The Institute of Scientific and Industrial Research, Osaka University	**KITAMURA Yoshifumi**
H30/A24	Research on development of flexible pressure sensors based on PVDF thin films	**TADAKI Daisuke** Research Institute of Electrical Communication, Tohoku University	**TADAKI Daisuke**
H30/A25	Influence of speaker's movie of speech utterance on the intelligibility and serial recall task	**OHTANI Tomoko** Art Media Center, Tokyo University of the Arts	**SAKAMOTO Shuichi**
H30/A26	Basic study on Perceptual User Interfaces for Intercation with IoT	**OMATA Masaki** Graduate Faculty of Interdisciplinary Research, Yamanashi University	**KITAGATA Gen**
H30/A27	A Study on Super High Performance Disaster Resilient Network Control	**UTSUMI Satoshi** Faculty of Symbiotic Systems Science, Fukushima University	**KITAGATA Gen**
H30/A28	Brain-like Integrated System using Thin-Film Devices	**KIMURA Mutsumi** Faculty of Science and Technology, Ryukoku University	**HORIO Yoshihiko**
H30/A29	Hardware security technologies for IoT	**OGUMA Hiroshi** Department of Electronics and Computer Engineering, National Institute of Technology, Toyama College	**HOMMA Naofumi**
H30/A30	Research on advanced IoT infrastructure based on Intelligent Edge	**SATO Fumiaki** Faculty of Science, Toho University	**OHORI Atsushi**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H30/A31	Study on knowledge acquisition and utilization for the diversifying information networks	**UEDA Hiroshi** Academic Center for Computing and Media Studies, Kyoto University	**KINOSHITA Tetsuo**
H30/A32	A Malware Detection System for Secure Campus BYODs	**SATOH Akihiro** Information Science Center, Kyushu Institute of Technology	**KITAGATA Gen**
H30/A33	Research of human life support based on agent IOT	**UCHIYA Takahiro** Information Technology Center, Nagoya Institute of Technology	**KINOSHITA Tetsuo**
H30/A34	Development of Metal Source/Drain CMOS on Ge-on-Insulator	**NAKASHIMA Hiroshi** Global Innovation Center, Kyushu University	**SAKURABA Masao**
H30/A35	Research about quantum devices utilizing phonon	**TAKADA Shintaro** National Metrology Institute of Japan, Research Institute for Physical Measurement, National Institute of Advanced Industrial Science and Technology	**OTSUKA Tomohiro**
H30/A36	Effect of sample geometry on the damping mechanism of CoFeB magnetic thin films with perpendicular easy axis using vector-network-analyzer ferromagnetic resonance spectroscopy	**Eli Christopher Inocencio Enobio** Department of Physics, Mindanao State University -Iligan Institute of Technology	**FUKAMI Shunsuke**
H30/A37	Research of on-chip terahertz antenna for ultra-wideband communication	**KANAYA Haruichi** Graduate School of Information Science and Electrical Engineering, Kyushu University	**SUEMATSU Noriharu**
H30/A38	Millimeter-wave array antenna using multi-layered substrate	**YOSHIDA Satoshi** Research Field in Engineering, Science and Engineering Area, Research and Education Assembly, Kagoshima University	**MOTOYOSHI Mizuki**
H30/A39	Development of a Wideband 2-GHz Sampl/Hold Circuit for dtectiong atmospheric water vapor	**KAWAGUCHI Noriyuki** Mizusawa VLBI Observatory, National Astronomical Observatory of Japan	**SUEMATSU Noriharu**
H30/A40	Mechanism and design of film-type electromagnetic noise suppressor for SHF band	**MUROGA Sho** Graduate School of Engineering Science, Akita University	**HASHI Shuichiro**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H30/A41	Quantification of basic visual properties in high dynamic range scenes	**NAGAI Takehiro** School of Engineering, Tokyo Institute of Technology	**KURIKI Ichiro**
H30/A42	A new congestion-based congestion control for the Internet	**UTSUMI Satoshi** Faculty of Symbiotic Systems Science, Fukushima University	**KITAGATA Gen**
H30/A43	Research for Agent-Based Management Support of IoT Services	**TANIMURA Yusuke** Graduate School of Medicine, Tohoku University	**KINOSHITA Tetsuo**
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**
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**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H28/B11	Asian HCI Research Community Development	**KITAMURA Yoshifumi** Research Institute of Electrical Communication, Tohoku University	**KITAMURA Yoshifumi**
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	**SHIOIRI Satoshi** Research Institute of Electrical Communication, Tohoku University	**SHIOIRI Satoshi**
H29/B02	Research on magnetic device for advanced communications equipment by observation and control of microstructure of magnetic material	**IKEDA Shinji** Faculty of Production Systems Engineering and Sciences, Komatsu University	**ISHIYAMA Kazushi**
H29/B03	Study on Semiconductor Device and its Integrated Electronics Systems for High Efficiency Energy Utilization	**CHIKYOW Toyohiro** Center for Material Research by Information Integration , National Institute for Materials Science	**HANYU Takahiro**
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	**HANYU Takahiro**
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	**HIROOKA Toshihiko**
H29/B09	Spatial User Interface by Understanding Human's Physical and Spatial Behaviors	**YAMAMOTO Goshiro** Kyoto University Hospital, Kyoto University	**TAKASHIMA Kazuki**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
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/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**
H29/B19	EM Information Leakage from Smart Devices and Its Countermeasure	**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-industry collaboration	**UEHARA Yoichi** Research Institute of Electrical Communication, Tohoku University	**UEHARA Yoichi**
H29/B21	Development of wide area vocal system for crows' behavior control	**TSUKAHARA Naoki** Center for Bioscience Research and Education, Utsunomiya University	**KITAMURA Yoshifumi**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H29/B23	Asynchronous Stochastic Computing for Brainware System	**ONIZAWA Naoya** Frontier Research Institute for Interdisciplinary Sciences, Tohoku University	**HANYU Takahiro**
H30/B01	Study of functional piezoelectric materials and applications to advanced communication devices	**KANAI Hiroshi** Graduate School of Engineering, Tohoku University	**SUZUKI Yôiti**
H30/B02	Magnetic devices utilizing material functionality	**ISHIYAMA Kazushi** Research Institute of Electrical Communication, Tohoku University	**ISHIYAMA Kazushi**
H30/B03	Inter-Tohoku District Spinics Research	**YAMAGUCHI Masahiro** Graduate School of Engineering, Tohoku University	**ISHIYAMA Kazushi**
H30/B04	Formation of spatial and temporal structures and various reactive fields in plasma flows	**ANDO Akira** Graduate School of Engineering, Tohoku University	**ISHIYAMA Kazushi**
H30/B05	Physics and application of spin dynamics in solids	**MATSUKURA Fumihiro** Advanced Institute for Materials Research, Tohoku University	**KANAI Shun**
H30/B06	Research on optical space mode	**HAMAMOTO Kiichi** Faculty of Engineering Sciences, Kyushu University	**YOSHIDA Masato**
H30/B07	Functionalization of oxide surfaces and its application to nanodevices	**HIROSE Fumihiko** Graduate School of Science and Engineering, Yamagata University	**HIRANO Ayumi**
H30/B08	Establishment of information science approach and psychological verification method for intellectual productivity acquisition in group discussion	**ITOH Yuichi** Graduate school of Information Science and Technology, Osaka University	**TAKASHIMA Kazuki**
H30/B09	Big data collection and analysis on mental and behavioral states of companion and wild animals	**TOUYAMA Hideaki** Faculty of Engineering, Toyama Prefectural University	**KITAMURA Yoshifumi**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H30/B10	Research on understanding of spatial auditory perception and enhancement of spatial audio technology	**OTANI Makoto** Graduate School of Engineering, Kyoto University	**SUZUKI Yôiti**
H30/B11	Creating smart and informative society for the elderly	**CHINTAKOVID/Thippaya** Department of Information Technology, Faculty of Information Technology, King Mongkut's University of Technology North Bangkok	**KITAMURA Yoshifumi**
H30/B12	Establishments of Optimal Design and High-Efficiency Control Scheme for High-Frequency Wireless Power Transfer Systems	**SEKIYA Hiroo** Graduate School of Engineering, Chiba University	**HORIO Yoshihiko**
H30/B13	High-dimensional neural dynamics to develop next-generation neural hardware	**HIROSE Akira** Graduate School of Engineering, Tokyo University	**SATO Shigeo**
H30/B14	Future Office Space and Interaction	**KITAMURA Yoshifumi** Research Institute of Electrical Communication, Tohoku University	**KITAMURA Yoshifumi**
H30/B15	The study of interactive entertainment systems for drone race	**SUGIYAMA Tomoyuki** Media Science Lab, Digital Hollywood University	**KITAMURA Yoshifumi**
H30/B16	Studies on the high value addition for digital contents based on the enrichment of media technologies	**AOKI Naofumi** Graduate School of Information Science and Technology, Hokkaido University	**SUZUKI Yôiti**
H30/B17	Development of swarm intelligence optimization based on nonlinear dynamical system theory and its application	**JINNO Kenya** Faculty of Knowledge Engineering, Tokyo City University	**HORIO Yoshihiko**
H30/B18	Empirical Research on Infrastructurization of Ubiquitous Computing	**MURAO Kazuya** College of Information Science and Engineering, Ritsumeikan University	**TAKAHASHI Hideyuki**
H30/B19	Improvement of deep learning for speech and music information processing	**CHIBA Yuya** Graduate School of Engineering, Tohoku University	**Jorge Alberto Trevino Lopez**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H30/B20	Understanding the brain mechanisms of "mind"	**TSUTSUI Ken-Ichiro** Graduate School of Life Sciences, Tohoku University	**SHIOIRI Satoshi**
H30/B21	Evaluation of sound information transmission performance in urban spaces on the basis of human auditory models	**Sato Hayato** Graduate School of Engineering, Kobe University	**SUZUKI Yôiti**
H29/S1	Project for creation of interdisciplinary, advanced science and technology based on coherent 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	**UEHARA Yoichi**
H29/S3	Innovation of Electrical Communication Systems based on Design	**SAWARAGI Tetsuo** Graduate School of Engineering, Kyoto University	**KITAMURA Yoshifumi**
H30/SI1	AI and Human Studies	**Su-Ling Yeh** AI and Advanced Robotics Center, Institute Graduate School National Taiwan University	**SHIOIRI Satoshi**

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
88	Japan-Korea International Symposium on Magnetic Devices and Materials	Aug.24,2018
89	International Symposium on Universal Acoustical Communication 2018	Oct.22-24,2018
90	Asian Wireless Power Transfer Workshop (AWPT2018)	Nov. 2-4,2018
91	3rd Japan-EU Flagship Workshop on Graphene and Related 2D Materials	Nov. 19-21,2018
92	The 2nd Tohoku-NTU U Symposium on Interdisciplinary AI and Human Studies	Nov. 24,2018
93	The 14th International Conference on Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP2018)	Nov. 26-28,2018
94	RIEC International Symposium on Human-Computer Interaction （The Third ACM SIGCHI Asian Symposium）	Dec.12-13,2018
95	16th RIEC International Workshop on Spintronics	Jan.9-10,2019
96	The 7th RIEC International Symposium on Brain Functions and Brain Computer	Feb. 22-23,2019
97	The 6th International Symposium on Brainware LSI	Mar. 1-2,2019
98	The 10th International Workshop on Nanostructures and Nanoelectronics	Mar. 6-7,2019

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. Hirohito Yamada
Manager	Associate Prof. Nobuyuki Matsuda

Acoustic Engineering	
Chair	Prof. Akinori Ito
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. Masahiro Yamaguchi
Manager	Associate Prof. Shuichiro Hashi
Manager	Assistant Prof. Tomoyuki Ogawa

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

Ultrasonic Electronics	
Chair	Prof. Hiroshi Kanai
Manager	Associate Prof . Mototaka Arakawa

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

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

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)
- 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)
- Faculty of Physics, M.V.Lomonosov Moscow State University (Russia)
- Center for Artificial Intelligence and Advanced Robotics, National Taiwan University (Taiwan)
- University of Calfornia, Santa Barbara (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)
- Chemnitz University of Technology (Germany)
- University of Regensburg (Germany)
- Carl von Ossietzky University of Oldenburg (Germany)
- Purdue University(U.S.A.)
- University of Salamanca (Spain)

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

1	IACR Transactions on Cryptographic Hardware and Embedded Systems
2	IEICE Electronics Letter (ELEX)
3	IEICE Transactions on Communications
4	IEICE Transactions on Communications (EB)
5	International Journal of Energy, Information and Communications
6	Japanese Journal of Applied Physics 特別号
7	Journal of Cryptographic Engineering
8	Neural Networks
9	Nonlinear Theory and Its Applications, IEICE
10	Nonlinear Theory and Its Applications, IEICE (NOLTA)
11	Optical Review
12	Scientific Reports (Nature Publishing Group)
13	Soft Robotics

International conferences programmed by a staff in RIEC

1	12th Global Symposium on Millimeter Waves (GSMM) 2019
2	15th RIEC International Workshop on Spintronics
3	2018 International Symposium on Nonlinear Theory and Its Applications
4	25th IEEE International Symposium on Asynchronous Circuits and Systems
5	ACM Conference on Interactive Surfaces and Spaces 2018
6	ACM SIGGRAPH Conference and Exhibition on Computer Graphics and Interactive Techniques in Asia 2018
7	ACM Symposium on Spatial User Interface 2018
8	ACM Symposium on Virtual Reality Software and Technology (VRST) 2018
9	ACSIN14
10	Asian CHI Symposium 2019: Emerging HCI Research Collection
11	Asia-Pacific Microwave Conference 2018
12	Asia-Pacific Workshop on Fundamentals and Applications of Advanced Semiconductor Devices (AWAD)
13	CIES Technology Forum
14	Compound Semiconductor Week / International Symposium on Compound Semiconductors (CSW/ISCS2019)
15	European Conference on Optical Communication (ECOC)
16	European Material Research Society Fall Meeting (MRS-E Fall Meeting 2018)
17	European Microwave Week 2018
18	IEEE 5G World Forum (WF-5G 2018)
19	IEEE EDS Distinguished Lecturer
20	IEEE International Conference on Communications (IEEE ICC 2018)
21	IEEE Symposium on Computers and Communications (ISCC 2018)
22	IEEE Virtual Reality 2019
23	IFIP TC.13 International Conference on Human-Computer Interaction (INTERACT 2019)
24	ImPACT International Symposium on Spintronics Memory, Circuit and Storage

25	Int. Conf. on Micro- and Nano-Electronics, in Zvenigorod (ICMNE2018)
26	International Conference on Recent Progress in Graphene Research (RPGR2019)
27	International Conference on Artificial Reality and Telexistence and Eurographics Symposium on Virtual Environments (ICAT-EGVE 2018)
28	International Conference on Cryptographic Hardware and Embedded Systems 2018
29	International Conference on InfraRed, MilliMeter Wave and TeraHerz (IRMMW-THz 2018)
30	International Conference on Solid State Devices and Materials
31	International Conferences on Modern Materials & Technologies in Montecatini Terme (CIMTEC 2020)
32	International Electorical Device Meeting
33	Optical Fiber Communication Conference (OFC)
34	Optical Nanofibre Applications: From Quantum to Bio Technologies
35	Opto-Electronics and Communications Conference (OECC)
36	RIEC International Symposium on Photonics and Optical Communications
37	Russia-Japan-USA-Europe Symposium on Fundamental & Applied Problems of Terahertz Devices & Technologies (RJUSE 2018)
38	Spintronics Workshop on LSI
39	Stanford & Tohoku University Joint Open Workshop on 3D Transistor and its Applications
40	Symposia on VLSI Technology and Circuits
41	The 10th International Conference on Ubiquitous and Future Networks (ICUFN 2018)
42	The 2018 IEEE Global Communications Conference (IEEE GLOBECOM 2018)
43	The 2018 IEEE International Conference on Communication, Networks and Satellite (COMNETSAT 2018)
44	The 2018 International Communications Quality and Reliability Workshop (IEEE CQR 2018)
45	The 2018 International Conference on Advanced Technologies for Communications (ATC 2018)
46	The 2018 International Workshop on Pervasive Flow of Things that is collocated (PerFoT)
47	The 20th ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM 2018)
48	The 22nd IEEE International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (IEEE CAMAD 2018)
49	The 2nd IEEE International Workshop on Information Flow Oriented Approaches in Internet of Things and Cyber-Physical Systems (InfoFlow 2019)
50	the 5th ACM International Conference on Nanoscale Computing and Communication (ACS-NanoComm)
51	The 5th International Conference of Information and Communication Technology (ICoICT 2018)
52	The 6th International Conference on Emerging Internet, Data & Web Technologies (EIDWT-2018)
53	The 6th International Symposium on Brainware LSI
54	The 7th RIEC International Symposium on Brain Functions and Brain Computer
55	The 9th International Symposium on Adaptive Motion of Animals and Machines (AMAM2019)
56	The International Conference on Information Networking 2019 (ICOIN 2019)
57	The SICE Annual Conference 2019 (SICE 2019)

58	Tohoku-Purdue Workshop on Novel Spintronics Physics and Materials for Future Information Processing
59	Tohoku-York-Kaiserslautern 6th Core-to-core Workshop on "New-Concept Spintronics Devices"
60	Topical Workshop on Heterostructure Microelectronics (TWHM)
61	When AI Meets Human Science: The 2nd Tohoku-NTU International Symposium on Interdisciplinary AI and Human Studies

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 2018, 23th, 24st and 25nd 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, 2018

Professors	21
Associate Professors	21
Assistant Professors	21
Research Fellows	9
Specially Appointed Professors	1
Specially Appointed Assistant Professors	2
Administrative Staff（Including Limited Regular Employees）	26
Technical Staff（Including Limited Regular Employees）	16
Total	117

2. Researchers (FY2018)

Foreign Researchers	Visiting Professors	6
	Visiting Asociate Professors	3
	Foreign Researcher	1
Cooperative Researchers of Private Company etc		11
JSPS Research Fellowship for Young Scientists		10
JSPS Postdoctral Fellowship for Overseas Researchers		0
Invitation Fellowship for Research in Japan		0
Contract Researchers		6
Contract Trainees		1
Total		38

3. Students

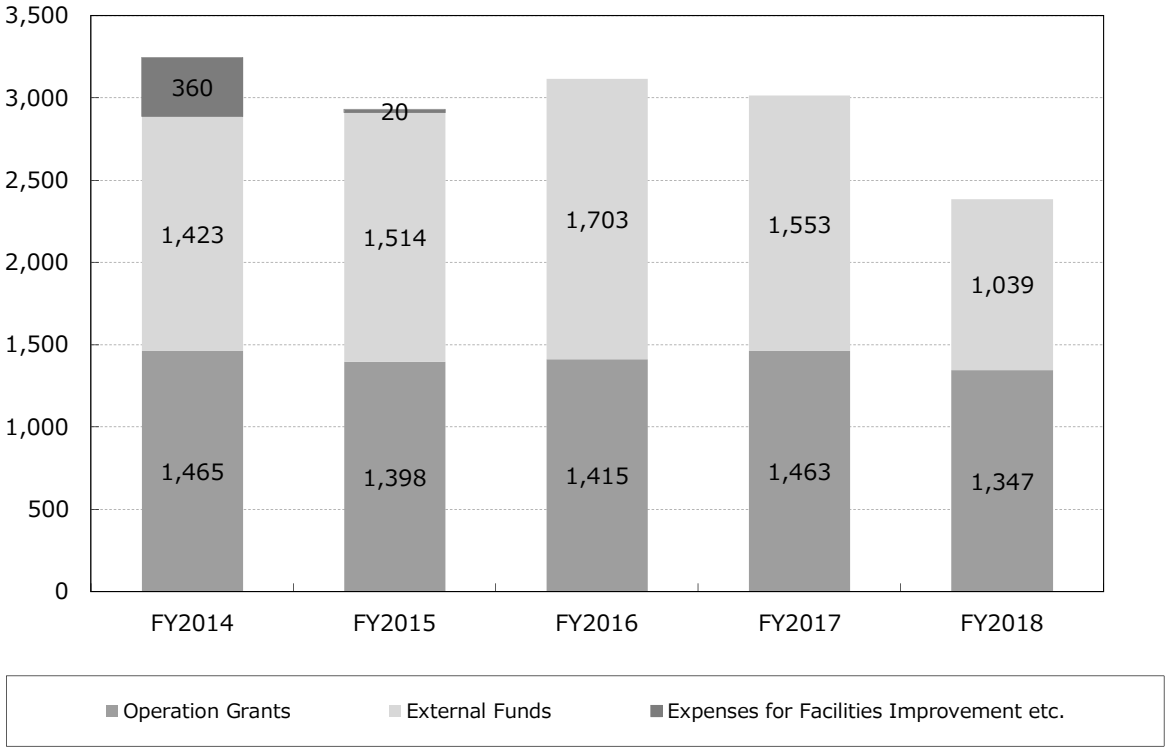
as of May 1, 2018

	School of Engineering	Graduate School of Information Science	Graduate School of Biomedical Engineering	RIEC	Total
Undergraduate Students	57 (3)				57 (3)
Master Course Students	73 (6)	51 (11)	8		132 (17)
Doctor Course Students	21 (6)	10 (5)	1		32 (11)
Institute Reserch Students				3 (2)	3 (2)
Total	151 (15)	61 (16)	9	3 (2)	224 (33)

4. Budget

Budget Shift

million yen



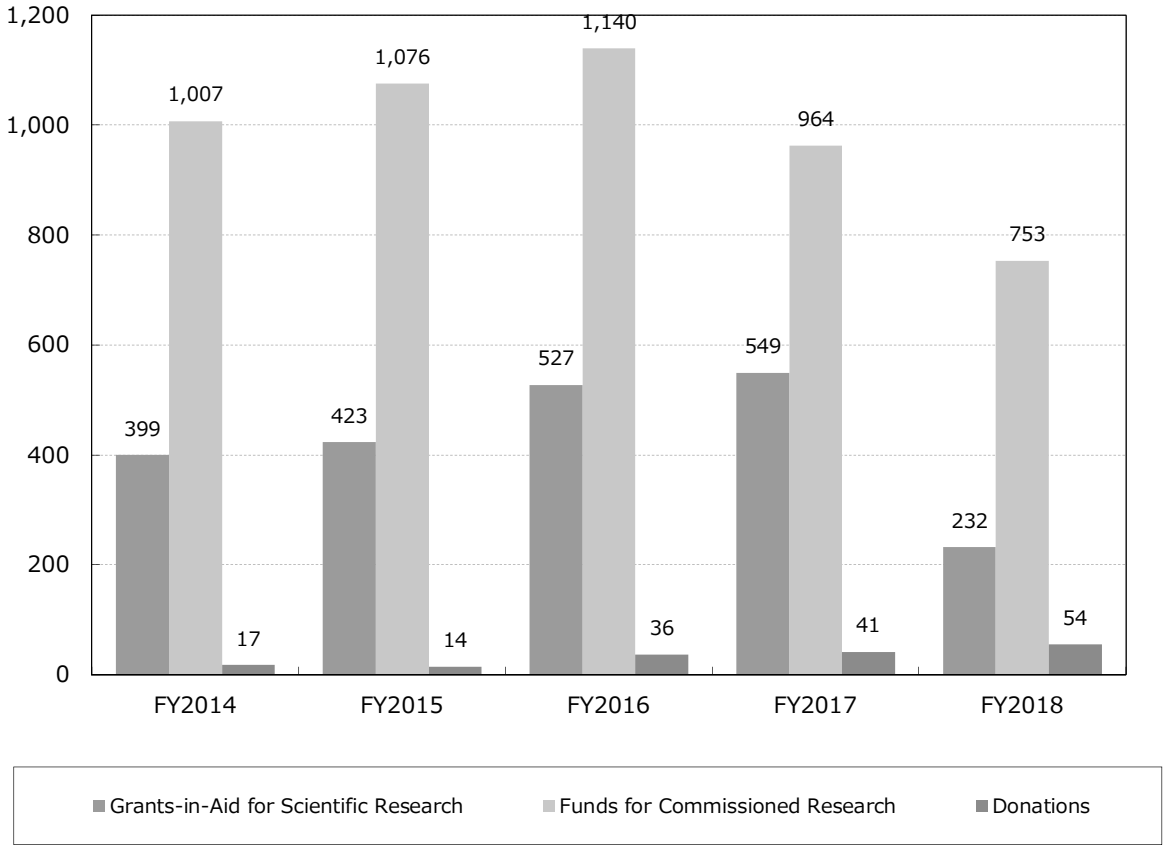
■ Budget Summary

thousand yen

Categories		FY2014	FY2015	FY2016	FY2017	FY2018
Operation Grants	Personnel Expenses	795,601	730,537	808,066	835,904	790,118
	Non-Personnel Expenses	668,941	667,582	606,599	626,824	556,937
Operation Grants Total		1,464,542	1,398,119	1,414,665	1,462,728	1,347,055
External Funds	Grants-in-Aid for Scientific Research	399,311	422,846	526,718	549,034	231,643
	Funds for Commissioned Research	1,007,060	1,076,220	1,140,386	963,585	753,391
	Donations	16,890	14,490	36,190	40,541	54,344
	Indirect Expenses	212,669	219,886	244,413	220,733	134,311
External Funds Total		1,423,261	1,513,556	1,703,294	1,553,160	1,039,378
Expenses for Reconstruction		0	0	0	0	0
Expenses for Relocation		359,770	20,011	0	0	0
Expenses for Facilities Improvement		0	0	0	0	0
Expenses for Facilities Improvement etc. Total		359,770	20,011	0	0	0
Total		3,247,573	2,931,686	3,117,959	3,015,888	2,386,433

External Funds

million yen



■ External Funds

thousand yen

Categories	FY2014	FY2015	FY2016	FY2017	FY2018
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Funds for Commissioned Research	1,007,060	1,076,220	1,140,386	963,585	753,391
Donations	16,890	14,490	36,190	40,541	54,344
Total	1,423,261	1,513,556	1,703,294	1,553,160	1,039,378

Annual Report 2018

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