Annual Report of Research Institute of Electrical Communication 2011

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1. Preface

On behalf of the Research Institute of Electrical Communication (RIEC) of Tohoku University, I would like to express my gratitude for the kind and unfailing support our work receives. I invite you all to read this report of RIEC’s research activities in fiscal 2011 and to give us your opinions and comments.

RIEC was established in 1935 as a research institute affiliated with the School of Engineering, where pioneering work in information and communications had already resulted in breakthroughs such as the Yagi-Uda antenna and the split-anode magnetron. Over the years, researchers dedicated to addressing the “theory and applications of intelligent information science and communication Engineering” have given back to society the fruits of their work in these fields. Close and smooth interpersonal communication is fundamental to maintaining and developing a flourishing and humane society, and the technologies that make this possible are taking on ever-increasing importance in the information age. To meet these social needs, RIEC is organized with a three-part structure: four Research Divisions whose programs have a twenty-year horizon; two research facilities working with a ten-year horizon; and the Research Center for 21st Century Information Technology, which aims at the practical application of IT results within a five-year time frame. Furthermore, through close collaboration between RIEC and the six major courses run by the Graduate Schools of Engineering, Information Sciences, and Biomedical Engineering that together make up the Group of Electrical Engineering, Communication Engineering, Electronic Engineering, and Information Engineering, we endeavor to train international researchers and highly skilled engineers while concurrently pursuing cutting-edge research.

In April 2010, RIEC took a further step forward when it was promoted from a National Center for Cooperative Research to a Joint Usage/Research Center. This represents an opportunity to demonstrate RIEC’s important role within the university, but also places great demands on us as we question the value of our existence and invite society’s evaluation. Last year, through the active management of over 70 nationwide cooperative research projects, we were able to expedite technology exchanges and liaisons with industry and government. We remain committed to do everything in our power to fully realize human communication, and I look forward to your continuing support and encouragement of our endeavors.

Professor Masataka Nakazawa
May 17, 2012
Director, Research Institute of Electrical Communication (RIEC),
Tohoku University
2. Organization Chart

Director

Advisory Council

Deputy Director

Research Divisions

Faculty Council

Information Devices Division
- Nano-Photoelectronics
- Quantum-Optical Information Technology
- Solid State Electronics
- Dielectric Nano-Devices
- Materials Functionality Design
- Magnetic Devices

Broadband Engineering Division
- Ultrahigh-Speed Optical Communication
- Applied Quantum Optics
- Advanced Wireless Information Technology
- Information Storage Systems
- Ultra-Broadband Signal Processing
- Basic Technology for Broadband Communication

Human Information Systems Division
- Electromagnetic Bioinformation Engineering
- Advanced Acoustic Information Systems
- Visual Cognition and Systems
- Ubiquitous Communications System
- Multimodal Computing

Systems & Software Division
- Software Construction
- Computing Information Theory
- Communication Network
- Information Contents
- Information Social Structure

Sponsored Division
- Environmental-Adaptive Information and Communication Engineering

Laboratory for Nanoelectronics and Spintronics
- Atomically Controlled Processing
- Semiconductor Spintronics
- Nano-Molecular Devices
- Nano-Spin Memory

Laboratory for Brainware Systems
- Real-World Computing
- Intelligent Nano-Integration System
- Microarchitecture
- New Paradigm VLSI System

Research Center for 21st Century Information Technology
- Project Planning Division
- Technology Development Division
  - Mobile Wireless Technology Group
  - Storage Technology Group
  - Intelligence Archive Group

Management Office for Safety and Health

Common Research Facilities

Flexible Information System Research Center

Fundamental Technology Center
- Machine Shop Division
- Evaluation Division
- Process Division
- Software Technology Division

Administration Office
- General Affairs Section
- Cooperative Research Section
- Library Section
- Accounting Section
- Purchasing Section
3. RESEARCH ACTIVITIES
Targets and achievements of the Information Devices Division

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

To accomplish this goal, we have the following 6 sub-divisions. The research fields include nano-scale photoelectronic conversions, quantum-optical information technology, novel transport properties in low-dimensional systems, new dielectrics-based nano-devices for information storage, and design of new materials having exotic functionalities. We also have a partnership with Atomically Controlled Processing (renamed to Nano-Integration Devices and Processing from 2012) section in the Laboratory for Nanoelectronics and Spintronics.

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

The research target and the summary of activities of each sub-division in 2011 are described in the following pages. The summary of activities of Atomically Controlled Processing section is described in the chapter of Laboratory for Nanoelectronics and Spintronics.
Nanophotoelectronics
Exploring optical and electronic properties of nanometer-sized structures and their applications in photoelectronic devices

Nanophotoelectronics Yoichi Uehara, Professor

[Research Target and Activities]
Our main interest lies in studying the physical and chemical phenomena that take place in nanometer-scale regions and their applications in nanophotoelectronic devices. We investigate the material properties of nanostructures through their optical responses to the local excitation induced by electrons from the tip of a scanning tunneling microscope (STM), as illustrated in Fig. 1. In this year, we have accomplished the ab-initio calculations of the dielectric functions of nanometer-scale domains of Ni(110)-(2x1) O surface. The theoretical predictions agreed well with the experimental results determined in 2010, showing that our interpretation on the origin of the dielectric properties are correct and that one can determine local dielectric functions with nanometer spatial and ps temporal resolution by STM light emission spectroscopy. We are developing a spectroscopic method having atomic spatial resolution in the THz spectral range. Surface phonon polaritons become radiative through the breakdown of translational symmetry by the presence of the tip. Thus strong THz emission is expected for STM light emission geometry. Functions of the prism in STM light emission were investigated this year. It was found that the prism gives directivity to the emission even in the THz region. Theoretical analyses of observed STM light emission spectra are crucial to determine local material properties from them. Classical theories of STM light emission cannot treat the prism-coupled STM light emission. We have successfully applied the finite differential time domain (FDTD) method, a numerical method for simulating electromagnetic phenomena, to the prism-coupled configuration. Attenuated total reflection (ATR) is a powerful tool for determining properties of thin films. Effects of roughness have scarcely been considered in analyzing ATR spectra. We have developed an ATR theory including effects of roughness.

[Staff]
Professor Yoichi, Uehara Dr.
Assistant 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.

[Papers]
Quantum-Optical Information Technology

Development of optoelectronic devices for quantum information and communication technology

Quantum-Optical Information Technology: Keiichi Edamatsu, Professor
Quantum Solid State Physics: Hideo Kosaka, Associate professor
Quantum Laser Spectroscopy: Yasuyoshi Mitsumori, Associate professor

[Research Target and Activities]
Our goal is to develop the quantum information devices utilizing quantum interaction between photons and electrons in solids. In 2011, we have achieved (1) development of novel entangled photon sources, (2) quantum media conversion from photons to electron spins in semiconductor quantum structures, and (3) development of heterodyne micro-pump-probe spectroscopy of single quantum dots.

[Staff]
Professor: Keiichi Edamatsu, Dr.
Associate Professor: Hideo Kosaka, Dr.
Associate Professor: Yasuyoshi Mitsumori, Dr.

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

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

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

[Papers]
Solid State Electronics Laboratory
Paving a Way for Introducing Graphene into Silicon Technology

Solid State Electroncis  Maki Suemitsu, Professor

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

In FY2011, we discovered that we can, by tuning the crystallographic orientation of the Si substrate as well as the growth condition, control the surface termination of the SiC film and the interfacial structure at the graphene/SiC boundary after the graphene growth. This is a property unique to GOS technology, which leads us to a feasible control of electronic structures of graphene. Process technology for graphene-based field-effect transistors (GFETs) has also made several progresses, which include observation of a cutoff frequency of 13 GHz for a GFET with a gate length of 3 μm.

[Staff]
Professor : Maki Suemitsu, Dr.
Assistant Professor : Hirokazu Fukidome, Dr.
Technical Assistant : Akemi Miura

[Profile]
Prof. Maki Suemitsu obtained bachelor degree on electronic engineering (1975), Ph.D on electronic engineering (1980). He started his service at Research Institute of Electrical Communication (RIEC) as research associate (1980), and became associate professor (1990). He then became professor at Center for Interdisciplinary Research (2003).
Since 2008, he has been professor at RIEC. He has been engaged mainly on surfaces of semiconductor thin films. He was awarded the 30th Kumagai prize of the best paper from the Vacuum Socieity of Japan (2005) and the Best Paper Award from the Surface Science Society of Japan (2011).

[Papers]

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Dielectric Nano-Devices
Research on Dielectric Nano Science and Technology

Dielectric Nano-Devices  Yasuo Cho, Professor

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

Major achievements of studies in 2011 are as follows: (1) Noncontact scanning nonlinear dielectric microscopy (NC-SNDM) was applied to the observation of Si(111) reconstructed surfaces. Images of the polarization distribution clearly distinguished disordered regions of the surface at the boundaries between the regular \((7 \times 7)\) domains. (2) Super-higher order nonlinear dielectric microscopy was developed. We measured the 3rd and 4th harmonics of SNDM signals, and experimentally clarified that the space resolution of SNDM images became higher according to increasing the harmonic numbers. (3) Charge accumulation in metal–oxide–nitride–oxide–semiconductor flash memories was investigated by using SNDM. Images of the distribution of the stored charges in oxide-nitride-oxide films were obtained with high resolution and contrast by detecting the high-order nonlinear permittivity.

[Staff]
Professor : Yasuo Cho, Dr.  Assistant Professor : Kohei Yamasue, Dr.
Visiting Professor : Koichiro Honda, Dr.  Technical Official : Yasuo Wagatsuma
Assistant Professor : Yoshiomi Hiranaga, Dr.

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

[Papers]

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Materials Functionality Design

Computational Design of Functional Materials for Spintornics Devices

Materials Functionality Design: Masafumi Shirai, Professor

[Research Target and Activities]

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

Our research activities in FY 2011 are as follows:

(1) Temperature dependence of magnetoresistance in tunnel junctions with half-metallic Heusler alloys

We investigated the temperature dependence of tunneling magnetoresistance (TMR) in Co$_2$MnSi/MgO/Co$_2$MnSi junctions on the basis of first-principles calculations [1]. We found that the tilting of interfacial Co spin moments resulting from the thermal fluctuations causes spin-flip scattering and reduces the TMR significantly (Fig. 1). The insertion of ultrathin Fe or FeCo layers into the interface enhances magnetic coupling and thus the TMR ratio at room temperature.

(2) Theoretical design of giant-magnetoresistive devices with half-metallic Heusler alloys

We investigated the spin-dependent transport properties of Co$_2$MnSi/XCo$_2$MnSi (X = Ag, Au, Al, V, Cr) trilayers [3]. We found that the matching of the Fermi surface predominantly determines the spacer dependence of the interfacial resistance. In particular, MnSi-terminated interfaces with Ag, Au, and Al spacers are promising for realizing larger magnetoresistance ratios.

[Staff]

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

[Profile]

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

[Papers]


Contact to Professor Masafumi Shirai: shirai@riec.tohoku.ac.jp
3.2 Broadband Engineering Division: Research Target and Results

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

(1) **Advanced Wireless Information Technology**

Toward the realization of a ubiquitous and broad-band wireless network, we are actively engaged in the research work on dependable and low power consumption advanced wireless IT. We cover the whole technical fields from the lower to higher layers, i.e., signal processing, RF/Mixed signal device, antenna, MODEM and network technologies. We are also working for the next generation wireless communication systems/devices which include a location / short message communication system via quasi-zenith satellites (QZS) and a fusion of various wireless communication systems “dependable wireless system.”

(2) **Ultra-Broadband Signal Processing**

We are developing novel, integrated electron devices and circuit systems operating in the terahertz region. One of our major concerns is a new material called “graphene”, a single-layered honeycomb-lattice carbon crystal. We have developed new types of high-performance gate-stack process technology for graphene-channel field-effect transistors (G-FETs) featured by DLC (diamondlike carbon) or SiCN dielectric insulators. This will open a new aspect of real-world operating ultrafast G-FETs.

We have also succeeded in development of record-breaking ultrahigh-sensitive plasmon-resonant-type terahertz detectors featured with our original asymmetric dual-grating gate HEMT (high electron mobility transistor) structure. An extremely high responsivity of 2.2KV/W and an ultralow noise-equivalent-power of $15pW/\sqrt{Hz}$ have been achieved at 1 THz radiation at 300K.

(3) **Ultrahigh-Speed Optical Communication**

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

This year, we successfully achieved 2.56 Tbit/s/ch transmission over 300 km, notable improvements in 256~512 QAM transmission by digital back propagation and
frequency-domain equalization techniques, and 800 Gbit/s-225 km OTDM-RZ/32-QAM transmission. Furthermore, we proposed a novel OTDM technique with an optical Nyquist pulse train, which offers the possibility of ultrahigh-speed and ultrahigh spectral efficiency simultaneously. Substantial improvement in dispersion tolerance was demonstrated in 160 Gbaud transmission compared to conventional pulses.

(4) **Applied Quantum Optics**

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

It is confirmed that the carrier density change in the semiconductor laser cavity can be reduced and low chirp intensity modulation with large response bandwidth can be achieved when semiconductor lasers are operated by injected intensity modulated signal light. The study on optically controlled passive feedback semiconductor lasers (PFLs) is also being continued. It is confirmed numerically that the 3 dB bandwidth of the PFL is enlarged to more than 50 GHz when the length of the external feedback cavity is optimized. Based on the design, the PFL is fabricated and is now being verified the effect of bandwidth enhancement experimentally.

(5) **Information Storage Systems**

High density data storage technology to store the large information is crucial to meet the strong demand of rapid information increase in the network. Low power consumption is another important performance.

We unveiled that areal density of 5 Tbit/inch², which is tenfold of current density, was difficult only by the bit-patterned media by theoretical approach with a computer simulation. For such high density, we clarified thermal assist recording technique that heats a narrow recording area is indispensable. Storage system technology to enhance the data transfer rate was also developed.

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

Synthetic aperture radars (SAR) are useful for all-weather surveillance and rescue. In this fiscal year we have developed various softwares for a real-time image, air-borne SAR under the research contract with Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Hardware of a real-time imaging radar: “Live SAR” has been successfully completed, with a high resolution (10 cm), small size and light weight (25 kg) at Ku-band. Scientists and engineers of universities and industries collaborate on the program.
Research Laboratory of Ultrahigh-Speed Optical Communication
Advanced optical communication technologies approaching the Shannon limit

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

[Research Target and Activities]
With the vast growth of Internet traffic, it has become increasingly important to realize a high-capacity and high-speed network. This laboratory aims to achieve a global ultrahigh-speed optical network by engaging in the research of ultrashort pulse generation and transmission.

This year, we successfully achieved 2.56 Tbit/s/ch transmission over 300 km, notable improvements in 256–512 QAM transmission by digital back propagation and frequency-domain equalization techniques, and 800 Gbit/s–225 km OTDM-RZ/32-QAM transmission. Furthermore, we proposed a novel OTDM technique with an optical Nyquist pulse train, which offers the possibility of ultrahigh-speed and ultrahigh spectral efficiency simultaneously. Substantial improvement in dispersion tolerance was demonstrated in 160 Gbaud transmission compared to conventional pulses as shown in Fig. 1.

[Staff]
Distinguished Professor: Masatake Nakazawa, Dr. Associate Professor: Toshihiko Hirooka, Dr. Associate Professor: Masato Yoshida, Dr. JSPS Fellow: Keisuke Kasai, Dr.

[Profile]
Masatake Nakazawa received the Ph. D. degree from the Tokyo Institute of Technology in 1980. He joined the Ibaraki Electrical Communication Laboratory, Nippon Telegraph & Telephone Public Corporation. He was a visiting scientist at MIT in 1984–1985. In 2001, he became a Professor of the Research Institute of Electrical Communication, Tohoku University, where he has been engaged in research on ultrahigh-speed optical communication including soliton transmission, nonlinear effects in fibers, mode-locked lasers, and photonic crystal fibers. He was promoted to a Distinguished Professor in 2008. He is currently the Director of the Institute.

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

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

[Papers]

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Applied Quantum Optics
Research on Innovative Highly Functional Photonic Semiconductor Devices

Highly Functional Photonics Hiroshi Yasaka, Professor

[Research Target and Activities]
Novel functional photonic devices including photonic integrated circuits are being investigated to explore new-generation photonic network systems.

Ultra high speed semiconductor photonic active devices are being investigated. It is confirmed that the carrier density change in the semiconductor laser cavity can be reduced and low chirp intensity modulation can be achieved when semiconductor lasers are operated by injected intensity modulated signal light. The study on passive feedback semiconductor lasers (PFLs) is also being continued. It is confirmed numerically that the 3 dB bandwidth of the PFL is enlarged to more than 50 GHz when the length of the external feedback cavity is set to ~ 170 μm. Based on the design, the PFL is fabricated and is now being verified the effect of bandwidth enhancement experimentally.

The study on highly functional semiconductor optical modulators is also being proceeded. Experiment for multi-carrier generation by using a semiconductor Mach-Zehnder modulator is carried out to realize compact multi-wavelength light sources (optical comb generators) applicable to dense wavelength division multiplexing (DWDM) systems. By applying RF signal to the modulator, 7~9 channels of optical frequency comb can be generated with channel peak power deviation of around 10 dB. Wavelength dependence of modulator's half-wavelength voltage (Vr) becomes a problem when the semiconductor Mach-Zehnder modulator is used in wide wavelength range and realizes "tunable wavelength optical comb generation". By adjusting the DC bias voltage applied to the modulator, same comb spectra can be obtained in wide wavelength range from 1525 to 1560 nm.

Photo of functional semiconductor photonic device (left), schematic structure of passive feedback semiconductor laser, PFL (middle), and calculated 3 dB bandwidth of the PFL as functions of feedback length and phase difference between lasing mode and feedback light.

[Staff]
Professor : Hiroshi Yasaka, Dr.

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

[Papers]
Advanced Wireless Information Technology
For the realization of the next generation mobile network

Noriharu Suematsu, 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.

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

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

[Staff]
Professor: Noriharu Suematsu, Ph. D
Assistant Professor: Suguru Kameda, Ph. D
Research Fellow: Shoichi Tanifuji, Ph. D

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

[Papers]
Information Storage System

Research on Large Capacity Information Storage System Using Perpendicular Magnetic Recording

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

[Research Target and Activities]
The amount of digital information is rapidly growing year by year, and was estimated to exceed 1000 Exa-byte in 2010. An extremely large storage capacity by high density magnetic recording is thus required. Novel perpendicular magnetic recording is explored in order to continuously develop the areal density of hard disk drives beyond the conventional density limit, i.e., a near-future target of 1 Tbit/inch^2 and ultimately exceeding 5 Tbit/inch^2. Theoretical studies including a micromagnetic computer simulation in association with an experimental approach are carried out to develop the next generation of high density perpendicular recording devices.

As we have proposed, the magnetic nano-structure of recording media is the most essential parameter to achieve high density perpendicular recording. Bit-patterned media (Fig 1) are one promising candidate. Recently we have clarified the possibility of an areal density of 5 Tbit/inch^2 in conjunction with heat assisted recording.

In addition to the studies on magnetic recording, a novel low-power consumption architecture was developed based on tiered operation of hard disk drives. (Fig. 2) A power reduction of 50% and high speed data transfer were confirmed from our simulation work.

[Staff]
Professor: Hiroaki Muraoka, Ph.D. (since 2000)
Associate Professor: Simon J. Greaves, Ph.D. (since 2003)
Research Associate: Kenji Miura, Ph.D. (since 2003)
Secretary: Chie Watanabe

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

[Papers]

Contact to Professor Hiroaki Muraoka: muraoka@riec.tohoku.ac.jp
Ultra-Broadband Signal Processing

Novel Millimeter-wave and Terahertz Integrated Electron Devices and Systems

Taiichi Otsuji, Professor
Tetsuya Suemitsu, Associate Professor

[Research Target and Activities]

Ultrafast photonic, electronic and plasmonic devices using graphene and III-V semiconductors.
(Left: terahertz amplified stimulated emission and its gain profile in optically pumped graphene, center: complementary inverter logic operation using graphene FETs, right: coherent terahertz emission from a plasmon-resonant HEMT.)

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

[Staff]
Professor: Taiichi Otsuji, Dr. Eng.
Associate Professor: Tetsuya Suemitsu, Dr. Eng.
Assistant Professor: Akira Satou, Dr. Eng.
CREST Researcher: Susumu Takabayashi, Dr. Eng.
JSPS Research Fellow: Stephane Albon Boubanga Tombet, Ph.D.   Secretary: Kayo UENO

[Profile]
Taiichi Otsuji: received the Dr. Eng. deg. from Tokyo Tech., Japan, in 1994. After working for NTT Labs., Japan, since 1984, he joined Kyutech in 1999, as an Assoc. Prof., being a prof. from 2002. Since 2005, he has been a Prof. at RIEC, Tohoku Univ., Japan. Recipient of the Outstanding Paper Award of the 1997 IEEE GaAs IC Symposium. Member of IEEE, OSA (senior), IEICE, and JSAP.

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

[Papers]

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Basic Technology for Broadband Communication

High Resolution Synthetic Aperture Radar for Civilian Applications

Fig.1 (up) Logo of “Live SAR”, (left) Antenna / gimbal assembly (10 kg).

Inutake Laboratory : Masaaki Inutake, Professor

[Research Target and Activities]

We are developing an air-borne synthetic aperture radar (SAR) for civilian applications. The SAR is useful for all-weather surveillance and rescue in disastrous fires and smokes. Scientists and engineers from both universities and industries collaborate on this research project.

Under the research contract with Ministry of Land, Infrastructure, Transport and Tourism (MLIT), a real-time imaging radar “Live SAR”, as shown in Fig.1 was successfully completed in 2010, with a high resolution (10 cm), small size and light weight at Ku-band, and in 2011, soft wares for image formation and user interface for “Live SAR” has been developed, as shown in Fig.2.

[Staff]
Visiting Professor : Masaaki Inutake, Dr.

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

[Papers]

Contact to Professor Masaaki Inutake : inutakem@riec.tohoku.ac.jp
Aims and Achievements of Human Information Systems Division

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

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

The goals and achievements in the fiscal year 2011 of each laboratory are described in detail below.

(1) Electromagnetic Bioinformation Engineering
(Aims) The aim of our division are to obtain the high accuracy sensor system for the signals from the human body or electric devices and to obtain the system for approaching action to the human body by using the nano-scale controlled magnetic materials and by the development of the devices under the functions of the magnetics.
(Achievements) We clarified the magnetic anisotropy of the magnetic thin film is the most important factor to obtain the high sensitive magnetic sensors. We proposed a new method to control the anisotropy by the difference of the thermal expansion constants, and we studied about the mechanism. On the works about the observation of the high frequency magnetic field distribution, we succeed to improve the special resolution and show the possibility for observation of the field distribution around the magnetic recording heads. We also worked on the magnetic actuator driven by external rotating field. Some kinds of biomimetic actuators were proposed. In addition, the magnetic field driven wireless pump was applied to use as the fully embedded ventricular assist device (artificial heart). The possibility was confirmed by the animal test.

(2) Advanced Acoustic Information Systems
(Aims) To realize future high-definition communication systems with rich and natural sense of presence, acoustic information processing technologies based on good knowledge of human auditory system as well as multimodal perception relating to hearing are studied.
(Achievement) In 2011, we deepen the understanding human spatiotemporal perceptual processes of audio-visual and audio-vestibular information. This is particularly important to realize future multi-modal information processing and communication systems. We clearly demonstrated which multimodal factors affected the sense of presence and verisimilitude...
perceived by multimodal contents. Based on this knowledge, mathematical model of these senses was proposed. We continued to develop methods, such as virtual auditory displays based on our accumulated knowledge of human auditory space perception, sensing and reproduction system based on High-order Ambinonics consisting of over 100 channels, 252-ch binaural spatial sound sensing system (SENZI). They are keenly required to realize super-definition audio-visual communications in near future.

(3) Visual Cognition and Systems

(Aims) Our goal is to understand the mechanisms of human visual perception in our brain to improve the design of visual information display in the information & communication technologies.

(Achievements) First, we have clarified a part of the neural basis for the shifts in visual attention, which moves independent of the gaze. We measured a kind of brain wave called steady-state visual evoked potentials (SSVEP), and analyzed changes in its amplitude and phase coherences, in comparison to the subject’s behavior. Our results implied that the synchronization of neural activities in the visual cortex plays a significant role in the shifts in visual attention. Second, we have found that the mechanisms for depth perception are based on a lower-level mechanism for motion detection in the retinal images. We have also demonstrated that simple numerical models can predict the general trends of the effect of contrast, displacement and vertical shifts shown in behavioral data. Third, we studied the binding mechanisms of color and motion information in human brain by using functional MRI technique. We found that the color and motion signal related to our perception are already bound at as early as the second- and third- visual areas. However, it also became necessary to study whether such a “bound” signal is yield by feedbacks from the higher order visual cortex or not.

(4) Ubiquitous Communications System

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

(Achievements) Major achievements in this year include (i) development of commercially applicable 60 GHz beam-forming antennas for portable terminals, (ii) 60 GHz CMOS power amplifiers, and phase shifters research and development close to commercially applicable level, (iii) improvement of indoor communications interruption probability by the factor of 10 leading to real Super Broad Band Indoor Wireless Communications deployment, (iv) a wide area sensor network proposal and contributions to IEEE Standardization aiming at standardization completion in FY2013.
Electromagnetic Bioinformation Engineering

Communication with human body

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

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

Fig. 1 Sensitive magnetic field sensor
Fig. 2 Magnetic actuator for capsule-endoscope

[Staff]
Professor: Kazushi Ishiyama, Dr.
Associate Professor: Shuichiro Hashi, 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]

Contact to Professor Kazushi Ishiyama : ishiyama@riei.tohoku.ac.jp
Advanced Acoustic Information Systems

Development of next generation communication systems

Advanced Acoustic Information Systems: Yōiti Suzuki, Professor
Acoustic Information Communications: Yukio Yukio, Associate Professor
Auditory and Multisensory Information Systems: Shuichi Sakamoto, Associate Professor

[Research Target and Activities]
The main interest of this laboratory is a study of the information processing in the human auditory system. We are, at the same time, aiming at the realization of a 'comfortable' sound environment exploiting digital signal processing techniques. Three-dimensional sound image control by high-definition virtual auditory displays based on simulating transfer functions of sound paths from sound sources to listeners' external ears, and a sound field simulator based on precise sound field analysis and control are two examples. These systems are expected to provide a high-quality 3D virtual sound space, which is keenly required to realize in the multimedia communications, cyberspace systems and super-definition audio-visual display systems. Moreover, in 2011, we put a lot of efforts to investigate the spatiotemporal integration process of multisensory information processing.

[Staff]
Professor: Yōiti Suzuki, Dr., Associate Professor: Yukio Iwaya, Ph.D., Shuichi Sakamoto, Ph.D.
Technical Official: Fumitaka Saito, Research Fellow: Zheng Lie Cui, Ph.D., Takuma Okamoto, Ph.D., Akio Honda, Ph.D., Hiroshi Shibata, Ph.D.

[Profile]
Yōiti Suzuki graduated from Tohoku University in 1976 and received his Ph. D. degree in electrical and communication engineering in 1981. His research interests include psychoacoustics and digital signal processing of acoustic signals. He served as a president of the Acoustical Society of Japan from '05 to '07. He is a fellow of the Acoustical Society of America.
Yukio Iwaya graduated from Tohoku University in 1991 and received his Ph. D. degree in information sciences in 1999. His research interests include three-dimensional acoustic space perception and development of its communication systems with high sense of presence.
Shuichi Sakamoto graduated from Tohoku University in 1997 and received his Ph. D. degree in electrical and communication engineering in 2004. His research interests include human auditory and multisensory information processing and development of advanced multimodal information systems.

[Papers]
Visual Cognition and Systems Laboratory
Understanding human visual system for the better communication with visual information

Visual Cognition and Systems: Satoshi Shioiri, Professor
Cognitive Brain Functions: Ichiro Kuriki, Associate Professor

[Research Target and Activities]
Our target is to understand the vision-related brain functions in order to apply the knowledge to realize human oriented information communication systems. We made achievements in the fields of visual attention, depth perception and color vision mechanisms. (1) We developed a technique to investigate the time course of visual attention by measuring steady-state visual evoked potentials (SSVEPs) to the flickering stimuli and compared with behavioral performance. The measurements suggested that phase coherence, rather than amplitude gain, determined the behavior. (2) We modeled two mechanisms for motion in depth based on motion/disparity energy detection. Model simulation predicted the general trends of the effects of contrast, displacement and vertical shift shown in the data. This suggests the physiological plausibility of the energy-based model of motion in depth. (3) We investigated the neural representation of color in human visual cortex by measuring brain activity by functional MRI technique and analyzed it with multi-voxel-pattern classification analysis.

Satoshi Shioiri: Professor Shioiri graduated Tokyo Institute of Technology and received Dr. Eng in 1986. He was a postdoctoral researcher at University of Montreal until May, 1989, and was a research fellow at Advanced Telecommunications Research Institute from June of 1989 to April of 1990. He joined Chiba University at May of 1990, as an assistant professor, an associate professor, and a professor. He has been a professor of Research Institute of Electrical Communication of Tohoku University, since May, 2005.

Ichiro Kuriki: Dr. Kuriki received Ph.D. from Tokyo Institute of Technology in 1996. He worked for Tokyo Institute of Technology (-1998) and the University of Tokyo (-2000) as a research associate before joining Communication Science Laboratories of NTT Corporation as a researcher. From January 2006, he joined the Research Institute of Electrical Communication, Tohoku University as an Associate Professor.

[Papers]

Contact to Professor Satoshi Shioiri: shioiri@riec.tohoku.ac.jp
Ubiquitous Communications System
R&D on Super Broadband Wireless Communications & ISWAN

Shuzo Kato, Professor
Hiroyuki Nakase, Associate Professor

[Research Target and Activities]
<Research Target>
The goal of ubiquitous communications is to provide communications environments in which everybody can communicate with anybody, anywhere and anytime without paying attention on the communications tools much. In order to realize this goal, the laboratory has been working on core technology research and development on Super Broadband Wireless Communications in which people can communicate at multi-Gbps freely.

<FY2011 Major Results>
A Beam forming module is developed successfully, that is ready for commercialization to realize Super Broadband Wireless Communications in 60GHz. The developed beam-forming RX module is shown in Fig.1 and its antenna directivity in Fig.2. Also ISWAN (Integrated Services Wide Area Wireless Networks) at 0.9 / 2.4GHz bands has been proposed to IEEE802.15.4K. The image of ISWAN is shown in Fig.3 aiming to be used for a disaster-relief network in case of emergency as well.

[Staff]
Prof.: Shuzo Kato, Ph. D,  Associ. Prof: Hiroyuki Nakase, Ph. D.  Assis Prof.: Hirokazu Sawada, Ph. D.
Technical staff: Lawrence Materum, Shigeru Yoshimiya, Technical assistant: Naomi Aizawa

[Profile]
Shuzo Kato  A Manager, Researcher and Engineer having a successful broad range of experiences from R&D, Manufacturing, Quality management, Product planning, Marketing, Sales, HRs in Japan and USA. Recently working on millimeter wave communications systems and its global(IEEE) standardization lead. Graduated from Faculty of Engineering, Tohoku University with Ph. D in 1977, Published over 200 technical papers and held over 90 patents (including the one that became Department of Defense (USA) standard in 1998), Fellow of the IEEE and IEICE Japan.

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

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

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

An overview of research results from Apr. 2010 to Mar. 2011 of these fields except the visitor section is described in this section.

(1) Software Construction

We have been researching on theoretical foundations for flexible yet reliable programming languages, and have been developing SML#, a new programming language in the ML family, that embodies some of our research results. The major results of 2011 academic year include the following. (1) Theoretical foundations for parallel tree operations: We have developed a systematic method of developing efficient parallel tree operations based on a theory of parametric polymorphism. (2) Development of the SML# Compiler: A major progress of the last year's development is design and implementation of a true separate compilation scheme and its interface language. We have also released SML# 0.90, which includes the separate compilation system.

(2) Computing Information Theory

Aiming at combining program transformation methods and automated theorem proving methods, we continued to pursue the possibility of program transformation by templates based on term rewriting. Based on a notion of natural higher-order inductive theorems, we showed sufficient criteria for applying transformation templates to higher-order programs. Although many automated termination provers have been proposed recently, little work is reported on automated confluence provers. We continued to develop an automated confluence prover ACP for term rewriting systems based on several divide-and-conquer methods. Applying the persistency and the decreasing diagram method, we implement a new method for proving confluence of term rewriting systems.

(3) Communication Network

A measurement function of agent's behavioral property is designed and implemented
based on the repository-based multiagent framework. A method of accumulating the distributed network information using Active Information Resource, and an infrastructure of agent-based network management system are proposed and evaluated through the simulation experiment and the implementation of a prototype system. Moreover, the advanced applications for intelligent distributed environment such as an agent-based sensor network for realizing the Smart-home and a knowledge-based electric power control method of multiagent-based microgrid, had been developed and demonstrated.

(4) Information Content
We focus on non-traditional contents other than movies, music and games, conducting comprehensive research on a variety of interactive content which creates new value through interactions with humans. This year we mainly conduct research projects on direct multi-touch interaction on a stereoscopic tabletop display, multi-touch elastic scroll and zoom techniques with content distortion, seamless interaction using a handheld projector in a perspective corrected multi-display environment, investigate of relationship between quality of inter-personal communication and content by using a media-space which consists of wall displays, floor displays, movable displays, audio speakers, and so on.
Software Construction
Foundations for Developing High-level and Reliable Programming Languages

Software Construction Atsushi Ohori, Professor

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

The major results of 2011 academic year include the following. (1) Theoretical foundations for parallel tree operations: We have developed a systematic method of developing efficient parallel tree operations based on a theory of parametric polymorphism. (2) Development of the SML# Compiler: In the last year, we developed the following methods and components. (i) Native thread support for POSIX threads. (ii) A true separate compilation scheme for ML and its interface language. We also have released a pre-release of fully functional version of the SML# compiler, which is a separate compilation system with all of our past development such as database integration.

[Staff]
Professor: Atsushi Ohori, Dr.
Assistant Professor: Katsuhiro Ueno, Dr.
Assistant Professor: Akimasa Morihata, Dr.

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

[Papers]

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**Computing Information Theory**

Towards a New Software Paradigm Arising from Computation and Proof

**Computing Information Theory** Yoshihito Toyama, Professor

**Computing logical system** Takahito Aoto, Associate Professor

[Research Target and Activities]

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

[Staff]

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

[Profile]

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

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

[Papers]


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Communication Network
Support of Cooperation and Communication between Human and Systems

Intelligent Communication Tetsuo Kinoshita, Professor

[Research Target and Activities]
In this year, the following studies had been done. (a) Evolutional Agent Systems: A measurement function of agent’s behavioral property is designed and implemented by using Repository-based multiagent framework. (b) Agent-based Network Management Technologies: A method of accumulating the distributed network information using Active Information Resource, and an infrastructure of agent-based network management system are proposed and evaluated based on the simulation experiment and the implementation of a prototype system (AIR-NMS). (c) Multiagent applications: The advanced applications for intelligent distributed environment had been studies, for instance, a knowledge-based electric power control method of multiagent-based microgrid, a method of supporting accumulation and integration of distributed information resource, and an agent-based sensor network for realizing the Smart-home. These results are published as 14 papers of both international journals and international conference proceedings.

[Staff]
Professor: Tetsuo Kinoshita, Dr.
Assistant Professor: Hideyuki Takahashi, Dr.

[Profile]
Tetsuo Kinoshita received the B.E. degree in electronic engineering from Ibaraki University, Japan, in 1977, and the M.E. and Dr.Eng. degrees in information engineering from Tohoku University, Japan, in 1979 and 1993, respectively. His research interests include agent engineering, knowledge engineering, knowledge-based systems and agent-based systems. He received the IPSJ Research Award, the IPSJ Best Paper Award and the IEICE Achievement Award in 1989, 1997 and 2001, respectively. Dr. Kinoshita is a member of IEEE(SM), ACM, AAAI, IEICE(Fellow), IPSJ(Fellow), and JSAI.

[Papers]

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Information Contents

Technologies for Interactive Content

Interactive Content Design

Yoshifumi Kitamura, Professor

[Research Target and Activities]

Good media content has the power to enrich our lives. The effectiveness of content delivery is becoming more and more important in a wide variety of fields, such as industry, education, culture, entertainment, and so on. Expectations of its use in the general public are also increasing. We focus on non-traditional contents other than movies, music and games, conducting comprehensive research on a variety of interactive content which creates new value through interactions with humans. This year we mainly conduct research projects on direct multi-touch interaction on a stereoscopic tabletop display, multi-touch elastic scroll and zoom techniques with content distortion, media-space for enhancing inter-personal communication, and so on.

[Staff]

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

[Profile]

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

[Papers]


Contact to Professor Yoshifumi Kitamura: kitamura@riec.tohoku.ac.jp
Information and Social Structure

Dynamic and Autonomous Control of Power Systems

[Research Target and Activities]
Life is an intrinsic part of nature. To be both pliant and sturdy in a complex environment requires an autonomy that is capable of creating the information needed to control the self. To “live,” a life system must on its own form a harmonious relationship with an unpredictably changing environment. It requires that it be capable of creating the information necessary for its own self-control. It is this autonomy that clearly distinguishes the world of life systems from the physical world, which indicates the necessary for the interdisciplinary studies on the world of life systems.

The unit commitment (UC) problem is strongly related to operations for a lot of systems, especially power systems. Many solutions have been extensively investigated. Conventional methods have been based on forecasted scenarios and have not been dynamic or autonomous. Distributed generation systems such as micro-grid systems have recently attracted attention because they help to preserve the global environment. These systems require dynamic and autonomous control because most of them use natural energy that changes unexpectedly and numerous units have to be controlled. However, as conventional methods are not dynamic or autonomous, we propose a new control to the UC system without any forecasted scenarios. We confirmed through computer simulations that our proposed method was able to dynamically and autonomously adapt to sudden environmental changes. The method was also confirmed to be robust and scalable while achieving almost optimal conditions of UC problem.

[Staff & Profile]
Visiting Professor: Masafumi Yano, Ph.D.
1992~: Professor, Research Institute of Electrical Communication (RIEC), Tohoku University.
2007~: General Director, Research Institute of Electrical Communication (RIEC), Tohoku University.
2010~: Professor Emeritus of Tohoku University and also Research Professor of RIEC

[Papers]

Contact to Professor Masafumi yano : masafumi@riec.tohoku.ac.jp
Information Social Structure

Disaster-oriented Strong Green ICT for Humans’ Life and Nature

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

In 2011, we have conducted a cooperative project called the Green ICT Innovation Promotion (PREDICT) based on the idea of “Symbiotic Computing.”

[Green ICT Innovation Promotion (PREDICT)]: In this project, Professor Norio Shiratori investigates the world’s first “Green-oriented Never Die Network Management Technology” that achieves greening (reduction of CO2 emissions by power saving) of the entire information system and high disaster tolerance at the same time. It is funded by The Ministry of Internal Affairs and Communications, Japan (2011-2014).

Our project goal is to reduce CO2 emission up to 10 30% during normal operation per information system, and to construct the infrastructure of information and communication systems with fault-tolerance in the event of a natural disaster, by effectively configuring wired and wireless networks. We also propose G-MIB (Green-oriented Information Base) to collect and control information to express working status of PCs effectively for energy saving of the entire information system. Through the research development, we are considering international standardization of our proposed information base.

[Staff]
Professor: Norio Shiratori, Dr. Secretary: Midori Horino

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

[Papers]


3-5. Environmental-Adaptive Information and Communication Engineering: goals and achievements in 2011

To embody a humanity-rich-communication by innovating information-and-communication technology (ICT) in the sustainable global society, we have to create human-friendly low-environmental-impact ICT devices and systems by using electronic materials and device-technology in the research fields of Nanotechnology, Spintronics and Information technology. Our aim is that the embodiment of low-environmental-impact information devices and electronic equipments based on fundamental theory of spin and electron; these are designed by systematic survey of the rapidly-changing industry needs and R&D trends. We report the summary of our activities in 2011.

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

Achievement
We evaluated the lowest gamma-ray dose for discoloration of plate-like silver nanoparticles adhered on plate-like α-alumina powder in the range of 3 – 3000 Gy (60Co) in various aqueous solution conditions. As a result of survey, it was found that the dose was tentatively 30 Gy at a certain solution condition. Radical species generated by radiation decomposition of water molecules probably discolor the powders. Though this dose is almost equal to that of existing chemical gamma-ray sensing materials, much higher sensitivity is required for our purpose. We are going to make the sensitivity higher by designing the solution condition. Further this material would be applied for a disposable gamma-ray-sensitive RF device.
Environmental-Adaptive Information and Communication Engineering

Does it contain Wisdom?

Environmental-Adaptive Information and Communication Engineering  Eiki Adachi, Professor

[Research Target and Activities]

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

Activities: The biggest Tsunami induced by the mega-earthquake destroyed the 4 nuclear plants in Fukushima at 11 March 2011. The destruction caused scattering of radioactive materials onto Fukushima and neighboring prefectures. This radioactive environmental pollution will affect our daily life over 30 years at least. We must remove the pollution or otherwise reduce deleterious effect on our daily life as far as possible. For this purpose, we have started to research a low-cost-high-sensitivity visualization device for detecting gamma-ray exposure, using our nanostructured material being developed. We evaluated the lowest gamma-ray dose for discoloration of plate-like silver nanoparticles adhered on plate-like α-alumina powder in the range of 3 – 3000 Gy (60Co) in various aqueous solution conditions. As a result of survey, it was found that the dose was tentatively 30 Gy at a certain solution condition. Radical species generated by radiation decomposition of water molecules probably discolor the powders. Though this dose is almost equal to that of existing chemical gamma-ray sensing materials, much higher sensitivity is required for our purpose. We are going to make the sensitivity higher by designing the solution condition. Further this material would be applied for a disposable gamma-ray-sensitive RF device.

[Staff]
Professor: Eiki Adachi, PhD.

[Profile]

[Papers]
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: Atomically Controlled Processing, Semiconductor Spintronics and Nano·Molecular Devices; together with the groups of Intelligent Nano·Integration System, Quantum·Optical Information Technology, and Ultra·Broadband Signal Processing. These groups cooperatively carry out the research aimed at establishing a world·wide COE in the research area of nanoelectronics and spintronics.
Highlights of Research Activities in 2011

Atomically Controlled Processing and Nano Integration

- Atomically Controlled Processing (J. Murota and M. Sakuraba)
  In this year, following experimental results have been obtained: (1) In thermal treatment of atomic-order nitrided Si_{0.3}Ge_{0.7}(100) at 400°C, Si_{3}N_{4} is dominantly formed at the surface. (2) Although Si_{1-x}Ge_{x} deposition rate on Si(100) and electrical activity of B atoms in B-doped Si(100) are changed by strain in Si(100), electrical activity of B in strained B-doped Si_{1-x}Ge_{x} on Si(100) is scarcely affected by strain in Si(100). (3) From thermionic emission characteristics of p-type resonant tunneling diode of strained SiGe/Si(100) with high Ge fraction, introduction of higher-barrier materials as well as atomic-order flatness control of heterointerface is important to improve resonant tunneling characteristics.

- Intelligent Nano-Integration System (K. Nakajima and S. Sato)
  (1) We have analyzed burst dynamics bound by potential with active areas by using a new concept virtual particle dynamics. Furthermore, we have tried to apply an inverse function delayed neuron model with high-order synapse connections to practical applications, and we have demonstrated the possibilities of them. (2) We studied the switching characteristics of stacked Nb/AlOx/Nb Josephson junctions with JSIM, which is a simulator for superconducting integrated circuits, and compared the results with experimental data. It has been found that the experimental data indicates much larger switching probabilities. We confirmed that it is necessary to identify electron temperature and stray capacitances for consistency with conventional theory. (3) We measured characteristics of electrical delay and high-speed operations in logic cell units for a superconducting 8-bit parallel multiplier. As a result, details of delay characteristics of logic cells were obtained by measurements of fabricated circuits. Meanwhile, we improved a threshold characteristic in the superconducting quantum interference device for a neural network solving N-Queens problem. An increase of the correct pattern ratio of N-Queens problem was confirmed by numerical simulations.

Semiconductor Spintronics and Information Technology

- Semiconductor Spintronics and Nano-Spin Memory
  (H. Ohno, Y. Ohno, F. Matsukura, and S. Ikeda)

  Our research activities focus on the establishment of fundamental technologies for future spintronics devices. The outcomes in the last fiscal year are following. (1)
Discovery of asymmetric nuclear magnetic resonance spectrum at low magnetic fields in a strained (110) GaAs quantum well. (2) Determination of domain wall width and exchange stiffness constant by analyzing domain structures in Ta/CoFeB/MgO. (3) Discovery of larger modulation ratio of magnetic anisotropy by electric filed in annealed Ta/CoFeB/MgO than as-deposited. (4) Generation of polarization-entangled photons with a high fidelity of 0.72 ± 0.05 from single GaAs quantum dots by an electric field. (5) Investigation of switching current and thermal stability in CoFeB/MgO based perpendicular easy axis MTJs (p-MTJs) with different junction size. (6) Acquisition of a materials design guideline for annealing-tolerability in the back-end process of CMOS integrated circuits. (7) Achievement of nonvolatility for system LSI in CoFeB/MgO based p-MTJ with the stepped structure.

Research activities in "Research and development of ultra-low power spintronics-based VLSIs" under "Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST Program)," initiated by CSTP. (1) The long range order parameter and perpendicular anisotropy ($K_{\perp}\approx1.8$ Merg/cc) were successfully enhanced by inserting CoFeB between 3.0 nm-thick FePd and MgO barrier. (2) L1$_0$-ordered MnAl films showed a large anisotropy with $\sim1\times10^7$ erg/cc and a low damping constant of 0.006. (3) Current-induced effective field was observed in Ta/CoFeB/MgO wire. (4) Operation of a fully parallel 6T-2MTJ nonvolatile TCAM (ternary content-addressable memory) cell and a FPGA (field-programmable gate array) cell fabricated by a 90-nm CMOS/MTJ process was verified. (5) World's fastest operation of 600 MHz in a nonvolatile MTJ/COMS latch circuit was verified.

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

  1. Ultra-Broadband Devices and Systems

  The goal of our research is to explore the terahertz frequency range by means of novel electron devices and systems. Graphene has massless electrons/holes, and their extraordinary carrier transport properties are expected to break through the limit on conventional device operating speed/frequency performances. We have developed graphene-channel FET's featured by novel gate-stack technologies utilizing SiCN or DLC (diamond-like carbon) dielectrics, which will lead to realization of terahertz transistors. We have also succeeded in observation of amplified stimulated emission of terahertz radiation from optically pumped graphene, proving our theoretical discovery of the possibility of the negative dynamic conductivity in a wide terahertz range, which will lead to new types of terahertz lasers.

  2. Ultrafast Electron Devices

  The target of this study is the compound semiconductor devices to explore ultimate operation speed of electron devices, such as millimeter- and sub-millimeter-wave
frequency range. In InGaAs-based high-electron mobility transistors (HEMTs), the SiCN mold technique is developed to form T-gate electrodes with detail control of the cross sectional shape. This technique will enable us to estimate the impact of the parasitic gate delay caused by the T-gate electrodes. The process technology for GaN-based HEMTs is also established to explore the millimeter-wave transistors with high breakdown voltages.

• Quantum-Optical Information Technology (K. Edamatsu and H. Kosaka)
  1. We have developed an efficient entangled-photon source with two-period quasi-phase-matched spontaneous parametric down conversion. We have demonstrated the generation of photon pairs that exhibit entanglement either in polarization or in frequency.
  2. We are developing a quantum media converter from a photon to an electron spin to realize a quantum repeater, which is expected to extend the transmission distance of quantum info-communication. We have demonstrated (1) time-bin photonic state transfer to electron spins instead of the conventional polarization state transfer, (2) electron spin state tomography with coherent Kerr effect, and (3) preparation of experiments for achieving photonic state transfer to a quantum memory in diamond.
  3. We have developed transient micro-pump-probe spectroscopy of single semiconductor quantum dots using heterodyne detection technique. We have succeeded in monitoring the ultrafast optical manipulation of a single quantum state in the single dot.

Nano-Molecular Devices

• Nano-Molecular Devices (M. Niwano and Y. Kimura)
  1. Fabrication of miniaturized hydrogen gas sensors using anodic titanium oxide nanotube films.

  Hydrogen gas sensors were miniaturized by the hybrid process between the photolithography technique and the anodization process of titanium. The channel length of the sensors was 3 μm. In the case of introducing 10 % hydrogen gas, the current of about 1 mA was sensed without using a comb-shaped electrode. The conductance change was about 20 times. This indicates that the hybrid process is a suitable method for miniaturization of gas sensors and reduction in power consumption and integration of gas sensors are expected.

  2. Investigation of the effect of F4TCNQ molecular doping to P3HT

  The effect of F4TCNQ molecular doping to P3HT was investigated using displacement current measurement (DCM) and infrared absorption spectroscopy. Infrared absorption spectra of doped P3HT films indicate that most of F4TCNQ molecules were associated
with generation of holes. The DCM curves suggest that the carrier injection did not occur at the interface between doped and non-doped P3HT layers although it takes place at the metal/organic film interface.

3. Simultaneous measurements of ion-channel currents at bilayer lipid membranes (BLMs) in Si substrates

Free-standing bilayer lipid membranes (BLMs) were reconstituted in microfabricated apertures in Si substrates and ion channel proteins were incorporated into the BLMs. Then this BLM device was extended to a multi-site array format. Simultaneous recording of channel current activities from the multiple BLMs was demonstrated by using a model channel gramicidin.

4. Artificial BLM chips based on Teflon-coated Si substrates

The surface of the above-mentioned Si chip was coated with insulator layers of Teflon and SiO₂. The insulator coatings worked to reduce the total capacitance, leading to noise reduction (1-2 pA in peak-to-peak) and elimination of current transients (< 0.5 ms). These electric properties are suitable for recording activities of biological ion-channel proteins useful for drug screening and biosensor applications.
Atomically Controlled Processing

Creation of Atomically Controlled Processing of Group IV Semiconductor and Application to Nano Heterodevices

[Research Target and Activities]
Development of atomically controlled processing technology in deposition and etching is quite important to fabricate future higher-performance ultralarge-scale integrated circuits (ULSIs) as well as quantum devices for new functions and to create new materials with novel properties which are different from that of conventional bulk materials. To overcome the limits of Si material properties and device miniaturization and to achieve on-chip integration of ultimate charge control into Si ULSIs, this laboratory aims to establish atomically controlled processing for nanometer-order artificial heterostructures of group IV semiconductors with atomically controlled surface and interfaces and nanometer-order three-dimensional patterning with molecular control to fabricate nanometer-order heterostructure devices. (Fig. 1)

In this year, following experimental results have been obtained: (1) In thermal treatment of atomic-order nitrided Si0.3Ge0.7(100) at 400 °C, Si3N4 is dominantly formed at the surface. (2) Although Si1-xGex deposition rate on Si(100) and electrical activity of B atoms in B-doped Si(100) are changed by strain in Si(100), electrical activity of B atoms in strained B-doped Si1-xGex on Si(100) is scarcely affected by strain in Si(100). (3) From thermionic emission characteristics of p-type resonant tunneling diode of strained SiGe/Si(100) with high Ge fraction, introduction of higher-barrier materials as well as atomic-order flatness control of heterointerface is important to improve resonant tunneling characteristics.

[Staff]
Professor : Junichi Murota, Ph.D.
Associate Prof. : Masao Sakuraba, Ph.D.

[Profile]
Junichi Murota received the B.E., M.E. and Ph.D degrees in electronic engineering from Hokkaido University in 1970, 1972 and 1985, respectively. He joined the Electrical Communication Laboratory, Nippon Telegraph and Telephone Public Corporation in 1972. In 1985 and 1995 he became an Associate Professor and a Professor, respectively, in the RIEC, Tohoku University. He was awarded the 3rd Yamazaki-Teiichi Prize (2003), the JSAP Fellow (2009) and the Commendation for Science and Technology by the MEXT (2010).

Masao Sakuraba received the B.E. degree in electrical engineering in 1990 and M.E. and Ph.D degrees in electrical and communication engineering in 1992 and 1995, respectively from Tohoku University. In 2002 he became an Associate Professor in the RIEC. He was awarded Young Researcher Award of Int. Conf. SSDM (1992) and 12th Research Encouragement Award of Tokin Foundation for Advancement of Science and Technology (2001).

[Papers]
Semiconductor Spintronics

Nanoscience and Nanotechnology for Spintronics and THz Lasers

Functional Spintronics: Hideo Ohno, Professor
Functional Spin Photonics: Yuzo Ohno, Associate Professor
Functional Spintronics Materials: Fumihiro Matsukura, Associate Professor

[Research Target and Activities]
We are working on the nanoscience and nanotechnology to control the quantum states in semiconductors, especially the spin states and optical transitions in the mid-infrared to THz. Materials of interest include GaAs/AlAs, InAs/(Al,Ga)Sb, GaN, and ZnO, with and without doping of magnetic elements, all grown by molecular beam epitaxy. We are investigating electrical, optical, magnetic properties of these materials and their application to new functional devices, such as memories and logic devices using spin states as well as quantum cascade lasers (QCL) with THz emission.

The outcomes in the last fiscal year are (1) Discovery of asymmetric nuclear magnetic resonance spectrum at low magnetic fields in a strained (110) GaAs quantum well. (2) Discovery of larger modulation ratio of magnetic anisotropy by electric filed in annealed Ta/CoFeB/MgO than as-deposited. (3) Generation of polarization-entangled photons with a high fidelity of 0.72 ± 0.05 from single GaAs quantum dots by an electric field.

[Staff]
Professor: Hideo Ohno, Dr.
Associate Professor: Fumihiro Matsukura, Dr.
Research Fellow: Ghali Mohsen, Dr.

Associate Professor: Yuzo Ohno, Dr.
Assistant Professor: Keita Ohtani, Dr.
Research Fellow: Katsuya Miura, Dr.

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

[Papers]
Nano-Molecular Devices
Control of surface and interface of molecular informational devices and development of novel nano-molecular devices

Nano-Molecular Devices: Michio Niwano, Professor
Nano-Electron Devices: Yasuo Kimura, Associate Professor

[Research Target and Activities]
Our research aims at application of semiconductor micro/nano-fabrication to semiconductor devices or many kinds of biosensors. We have investigated development of 1) a biomolecular sensing system using Si fabrication technologies and 2) a nanofabrication method using electrochemical processes such as anodization of valve metals.
1) Fabrication of porous Ti/Al composite counter electrodes for dye-sensitized solar cells
Porous Ti/Al composite counter electrodes were developed for dye-sensitized solar cells (DSCs). The composite counter electrodes reduced the sheet resistance to increase the fill factor.
2) Simulations of pharmacological actions in the basal ganglia circuit
Computational simulations were carried out to investigate pharmacological effects in the basal ganglia (BG). They demonstrated that dopamine depletion in the BG and the frontal cortex causes delay of eye movements and induces oscillation of the neuronal activity in the BG.
3) Bilayer lipid membranes (BLMs) in Teflon-coated silicon chips
Low-noise silicon (Si) chip was proposed as a platform for suspending stable BLMs. After coating the microfabricated Si chips with insulators (Teflon and SiO2), current noise was markedly reduced. Single-channel activities were clearly resolved at BLMs formed in the Si chips, demonstrating the usefulness of the insulator coatings.

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

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

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

[Papers]

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Nano-Spin Memory
Research of spin based device and memory

Nano-Spin Memory  Shoji Ikeda, Associate Professor

[Research Target and Activities]
We are developing technologies to realize advanced spin memory and logic devices using magnetic tunnel junctions (MTJs). In our group, the following results were obtained.
1) We investigated junction size dependence of thermal stability factor \( E/k_BT \) in perpendicular anisotropy CoFeB/MgO MTJs (p-MTJs) which have attracted much attention as a core storage device in spintronics based VLSIs. The \( E/k_BT \) maintains almost constant value within d range from 81 nm to 40 nm. 2) We have investigated the origin of reduced tunnel magnetoresistance (TMR) ratio of the p-MTJs with 40 nm annealed at 350-400°C, which is desired in the back-end process of CMOS integrated circuits. We find that reduction of dipole coupling, which is one of sources for lack of AP configuration, restores the TMR ratio even after annealed at 400°C. 3) We developed a CoFeB/MgO based p-MTJ with the stepped structure using 300 nm reference layer and 100 nm recording layer in diameters. We obtained thermal stability factor \( E/k_BT=72.9 \) in P state and 70.1 in AP state by using stepped structure, indicating that nonvolatility for system LSI was achieved.

[Staff]
Associate Professor : Shoji Ikeda, Ph.D.
Research Fellow : Katsuya Miura, Ph.D.
Research Fellow : Tadashi Yamamoto

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

[Papers]

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Laboratory for Brainware Systems
Research Targets and Activities of Laboratory for Brainware Systems

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

We aim at establishing scientific and technological foundations for Real-World Computing (section), New Paradigm VLSI System (section), Intelligent Nano-Integration System (section), Microarchitecture (section), Cyber Robotics (planned section), and Next-Generation Human Interface (planned section). The Laboratory for Brainware Systems consists of the above six sections which cooperatively carry out the research. At the same time they serve as a laboratory for nation-wide cooperative research in the field of Brainware systems.

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

[Research Target]

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

New Paradigm VLSI System Section: Performance degradation of System on a Chip (SoC) or Network on Chip (NoC) due to wiring complexity, power dissipation and characteristic variation of materials/devices is increasingly getting a serious problem in recent VLSI era. Our research activity is to solve the above problem by the following two ways: the use of logic-in-memory architecture based on nonvolatile storage elements combined with CMOS logic, and the use of asynchronous data-transfer scheme based on multiple-valued current-mode logic, which would open up a novel VLSI chip paradigm, called a “new-paradigm VLSI system.”

Intelligent Nano-Integration System Section: Our research activities cover the fields of architectures of Brain computing systems, characterization and application of artificial neural networks, computer aided designs and fabrications of intelligent integrated circuits, and exploitation of new devices for neural circuits. At present research is focused on the large scale integration of Brain computing system and exploitations of new neural devices proposing a neuromorphic quantum computation.
Microarchitecture Section: The research activities in microarchitecture lab. include architecture and circuit design of mixed-signal SoC applicable to sensor network system to explore brain activity research along with mixed-signal topdown design methodology.

[Research Activities]

Real-World Computing Section (Ishiguro Laboratory): The main contributions achieved in 2011 can be summarized as follows: (1) We have constructed a modular robot that exhibits versatile oscillatory patterns and switches spontaneously between the patterns, inspired by the plasmodium of true slime mold; (2) We have demonstrated through mathematical modeling and simulations that only two local reflexive mechanisms, which exploit sensory information about the stretching of muscles and the pressure on the body wall, are crucial for realizing snakes’ scaffold-based locomotion; (3) We have constructed a model of gait transition of quadruped locomotion by fully exploiting resonance; (4) We have proposed a CPG model for quadruped locomotion, which relies more on physical communication between the limbs rather than neural communication; (5) We have derived an autonomous decentralized control scheme called a curvature derivative control for two-dimensional sheet-like robot; (6) We have proposed a CPG model for adaptive bipedal locomotion by fully exploiting the sensory information yielded from the softness of the feet; (7) We have derived an autonomous decentralized control scheme that can reproduce the locomotion of earthworms.

New Paradigm VLSI System Section (Hanyu Laboratory): In this year, we have successfully fabricated a 4-input nonvolatile LUT (look-up table) circuit, and designed a 6-input nonvolatile LUT circuit. Our approach to solving PVT-variation effects is to use "redundant" MTJ devices, which are connected in parallel and/or series to original MTJ devices (used as configuration memory). By sharing write-control MOS transistors, the hardware overhead of write-control circuits can be greatly reduced. In fact, the transistor counts of the proposed 4-input and 6-input LUT circuits are reduced to 48 percent and 38 percent, respectively, in comparison with those of a conventional nonvolatile LUT circuit. In this year, we have also successfully designed and fabricated new nonvolatile TCAM cell circuits for performing a parallel data-search operation. Two kinds of nonvolatile TCAM cell circuits: 6 MOS transistors with 2 MTJ devices (6T-2MTJ) and 7 MOS transistors with 2 MTJ devices (7T-2MTJ), are proposed. The former is oriented to less transistors, the latter is oriented to shorter switching delay. Furthermore, we have also developed a fine-grained power-gating scheme in asynchronous control circuits. Since power-switch control signals are appropriately generated by slightly modifying asynchronous control signals, the hardware overhead of power-gating controller, which is a serious problem in the conventional power-gating system, is greatly reduced.

Intelligent Nano-Integration System Section (Nakajima-Sato Laboratory): (1) We have tried to apply an inverse function delayed neuron model with high-order synapse connections to practical applications. (2) We studied the switching characteristics of stacked Nb/AlOx/Nb Josephson junctions with JSIM, which is a simulator for superconducting integrated circuits, and confirmed that it is necessary to identify electron temperature and stray capacitances for consistency with conventional theory. (3) We measured characteristics of electrical delay and high-speed operations in logic cell units for a superconducting 8-bit parallel multiplier, and improved a threshold characteristic in the superconducting quantum interference device for a neural network solving N-Queens problem. An increase of the correct pattern ratio of N-Queens problem was confirmed by numerical simulations.

Microarchitecture Section (Masui Laboratory): We have been investigating architecture and circuit techniques for low-power and low-cost CMOS transceiver ICs applicable to wireless sensor network. We have developed a dual-band (315MHz/433MHz) 3.5mW, 5µsec settling-time, 15µsec start-up time fractional-N PLL synthesizer, where a loop-optimization method for the 4th order PLL is elaborated for the 5µsec settling-time, and a fast calibration scheme storing the process tuning data in a nonvolatile memory fabricated by a standard CMOS is proposed for the 15µsec start-up time. We have also developed a low-power bandpass filter based on an active-Gm-RC architecture, where the circuit topology is optimized for the filter characteristics and the associated tuning, and a 15µsec start-up time circuit parameter optimization method is established as well.
Real-world Computing
Toward Understanding Design Principle for Life-like Resilient Systems

Real-world Computing Akio Ishiguro, Professor

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

Fig.1: Soft-bodied amoeboid robot driven by a fully decentralized control scheme extracted from true slime mold
Fig.2: Decentralized control of a snake-like robot that exhibits highly adaptive and resilient properties
Fig.3: Quadruped robot driven by a fully decentralized neural network-based control.

[Staff]
Professor: Akio Ishiguro, Dr.
Assistant Professor: Dai Owaki, Dr., Takeshi Kano, Dr., Kazuhiro Sakamoto, Dr.

[Profile]
Akio Ishiguro received B.E., M.E., and Ph.D. degrees from Nagoya University in 1987, 1989, and 1991, respectively. From 1991 to 1997, he was with Nagoya University as an assistant professor. From May 1997 to 2006, he was an associate professor of the Department of Computational Science and Engineering, 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.

[Papers]

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Intelligent Nano-Integration System
Basic Technology of Integrated System for Intelligent Processing

Intelligent Nano-Integration System, Koji Nakajima, Professor
Integrated Superconducting Quantum System, Shigeo Sato, Associate Professor

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

Research Activities in 2011:
(1) We have analyzed burst dynamics bound by potential with active areas by using a new concept virtual particle dynamics. Furthermore, we have tried to apply an inverse function delayed neuron model with high-order synapse connections to practical applications, and we have demonstrated the possibilities of them. (2) We studied the switching characteristics of stacked Nb/AlOx/Nb Josephson junctions with JSIM, which is a simulator for superconducting integrated circuits, and compared the results with experimental data. It has been found that the experimental data indicates much larger switching probabilities. We confirmed that it is necessary to identify electron temperature and stray capacitances for consistency with conventional theory. (3) We measured characteristics of electrical delay and high-speed operations in logic cell units for a superconducting 8-bit parallel multiplier. As a result, details of delay characteristics of logic cells were obtained by measurements of fabricated circuits. Meanwhile, we improved a threshold characteristic in the superconducting quantum interference device for a neural network solving N-Queens problem. An increase of the correct pattern ratio of N-Queens problem was confirmed by numerical simulations.

[Staff]
Professor: Koji Nakajima, Dr. Associate Professor: Shigeo Sato, Dr.
Assistant Professor: Takeshi Onomi, Dr.

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

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 an associate professor.

[Papers]

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Ubiquitous society has been established by the deployment of various wireless systems ICs, and it demands advances in mixed-signal (analog and digital) design technique as well as higher integration through SoC (System on a Chip). Our research activities include architecture and circuit design of mixed-signal SoC applicable to sensor network systems for the investigation of brain activities researches as well as design automation of RF/analog circuit. We propose a mixed-signal platform to maximize the design creativity by utilizing IP-based digital design methodology to various RF/analog and mixed-signal circuits. From this concept, we have developed a 3.5mW, 5μsec settling time, 15μsec start-up-time fractional-N PLL frequency synthesizer for a dual band (315MHz/433MHz) smart key applications with a self-dithered sigma delta modulator to minimize the fractional spurious.

[Staff]
Professor: Shoichi Masui, Dr.
Visiting Associate Professor: Takana Kaho, Dr.

[Profile]
Shoichi Masui received the B. S. and M. S. degrees from Nagoya University, Nagoya, Japan in 1982, and 1984, respectively, and received the Ph. D. degree from Tokyo Institute of Technology in 2006. From 1990 to 1992, he was a Visiting Scholar at Stanford University, Stanford CA, and a Visiting Scholar at University of Toronto, Toronto ON, Canada in 2001. Since 2007, he is a professor in Research Institute of Electrical Communication, Tohoku University. He is the recipient of a commendation by the Minister of Education, Culture, Sports, Science, and Technology, Japan, in 2004 for his research achievements on FeRAM.

[Papers]
New Paradigm VLSI System Research Group
Realization of a New-Paradigm VLSI-Computing World

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

Fig.2: Compact nonvolatile LUT circuit using series/parallel connected MTJ devices.

Fig.3: Differential current-mode logic circuit with MTJ-based variation compensation capability.

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

As this year’s research results in nonvolatile-logic area, we have succeeded the fabrication of MTJ (Magnetic Tunnel Junction)-based fully-parallel ternary content-addressable memory (TCAM) prototype chip (Fig.1), which could achieve zero-standby-power with minimum transistor counts. We have also designed a 6-input nonvolatile lookup table (LUT) circuit using series/parallel-connected MTJ devices (Fig.2), and demonstrated its compactness with PVT-variation resilience. Furthermore, we have proposed a process-variation-aware VLSI design architecture based on MTJ/MOS circuit hybrid structure (Fig.3), and confirmed its effectiveness through the evaluation of variation resistance of a differential current mode logic gate with Vt-tuning function.

[Staff]
Professor: Takahiro Hanyu, Dr.
Assistant Professor: Masanori Natsui, Dr.

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

[Papers]

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IT-21 center

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

[Research Target and Activities]

The purpose of the IT-21 center is development of practical technologies for IT based on the advanced technologies of RIEC with the partnership among Industry, Government and University. The term of development is limited less than 5 years. The projects are 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. From 2007, the new 2 projects were started.

1. Development of Dependable Wireless System and Devices

Our new project “Development of Dependable Wireless System and Devices” was accepted in 2007 as the Japan Science and Technology Agency (JST) CREST type research program “Fundamental Technology for Dependable VLSI System.” The project has been executed by the collaborations between RIEC including IT21 mobile wireless technology group, major Japanese mobile terminal manufacturers and other universities. In this project, concept of Dependable Air, which is multi-mode and multi-band dependable wireless network, is proposed. The targets of this project are (a) all IF dependable wireless network which can realize a communication speed of 1Mbit/s~10Gbit/s, (b) all Si CMOS mixed signal LSI with frequency range of 500MHz~70GHz, (c) LSI development of frequency domain equalizer technology, and (d) scalable AD converter. In 2011 the project attained (1) All Si CMOS integration of millimeter-band transmitter and receiver, (2) Evaluation technology for wireless dependability by a frequency domain channel estimator, (3) Design and evaluation of the compact antenna for millimeter-band.

2. Development of Low Power Consumption Mass Storage HDD Systems

A project “Development of super high-speed mass storage HDD systems” started in 2007 under the collaborations between RIEC including IT21 storage technology group, major Japanese HDD manufacturers and other related laboratories within Tohoku University. The goal of the project is the reduction of power consumption of mass storage system. Perpendicular recording technology for ε Tbits/inch² areal recording density is investigated, which reduces the number of HDDs by 1/10, and low power architecture of tiered RAID system. In 2011, (1) From numerical simulations with a super-computer and experiments, it was shown that bit-patterned media with high gradient writing realizes the areal density of 5 Tbit/inch², (2) Thermal assisted recording would be necessary to attain the high writing gradient, (3) A tiered system architecture for high performance and low power consumption was developed.

[Staff]

Director: Hiroaki Muraoka, Professor
Project Planning Division
Makoto Furunishi, Visiting Professor
Technology Development Division (Mobile Wireless Technology Group)
Kazuo Tsubouchi, Visiting Professor
Tadashi Takagi, Visiting Professor
Technology Development Division (Storage Technology Group)
Kazuhisa Fujimoto, Professor
Hajime Aoi, Visiting Professor
Takehito Shimatsu, Associate Professor
Kiyoshi Yamakawa, Visiting Associate Professor
IT21 Center Mobile Wireless Technology Group
For Realizing Dependable Air

Kazuo Tsubouchi, Visiting Professor (Project Leader)
Tadashi Takagi, Visiting Professor

[Research Target and Activities]
“Development of Dependable Wireless System and Devices” project was accepted in 2007 as the Japan Science and Technology Agency (JST) CREST type research program.
1. **All Si CMOS RFIC**: For realizing Dependable Wireless System (DWS), we have developed 5GHz- and 60GHz-band RF circuits using 90nm Si-CMOS technology.
2. **Digitally Assisted Compensation Technology**: We have developed a novel frequency domain equalizer (FDE) technology implemented to an application specific integrated circuit (ASIC). We have demonstrated a transmission test under multipass fading environments. Due to the FDE, we have realized to improve bit error rate (BER) characteristics. Conventionally, FDE technology has been evaluated by simulation. Here, we have been able to realize it by experiment.
3. **Adaptive and Scalable ADC/DAC (Analog-to-Digital Converter/ Digital-to-Analog Converter)**: We have devised a current mode pipeline ADC, which is suitable for process miniaturization and low supply voltage. We have designed several core circuits of the ADC and have realized static characteristics.

[Staff]
Visiting Professor: Kazuo Tsubouchi, Ph.D (since 2010)
Visiting Professor: Tadashi Takagi, Ph.D (since 2010)

[Profile]
Kazuo Tsubouchi  Prof. Tsubouchi received the Ph.D. degree in Electronics Engineering from Nagoya University in 1974. In 1974, he joined the Research Institute of Electrical Communication, Tohoku University. In 1982, he spent at Purdue University as a Visiting Associate Professor. From 1993 to 2010, he was a professor of RIEC, Tohoku University. From 2002 to 2010, he was the director of IT-21 Center. He is currently a visiting professor. He received the 2005 Achievement Award from the IEICE, and “Minister of Education, Culture, Sports, Science and Technology, Award” in the Award for Persons of Merit in Industry-Academia-Government Collaboration in FY2007, et al. He is a member of the IEEE, the IEICE, the Physical Society of Japan, the Japan Society of Applied Physics, and the Institute of Electrical Engineers of Japan.

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

[Papers]
Development of low power consumption mass storage HDD systems

Kazuhiisa Fujimoto, Professor
Takehito Shimatsu, Associate Professor

[Research Target and Activities]
A new project :Development of super high-speed mass storage HDD systems started in August 2007 under the collaborations between RIEC including IT21 storage technology group and major Japanese HDD manufacturers. The goals of this project are to develop the perpendicular recording technologies in the order of Tb/s/inch² recording density and, to develop the system architecture for realizing large capacity, high performance and low power consumption storage systems. This year, we experimentally estimated the write margin of bit patterned media consisting of magnetically-hard/soft stacked dot arrays with dot diameter of 20 nm (a recording density in the order of Tb/s/inch³). We simulated that the recording density of 5 Tb/s/in² can be achieved with a write margin of 4-5 nm for thermally-assisted magnetic recording on bit patterned media. Moreover, we experimentally demonstrated that L1₁Co₁₅Ni₃₅Pt₅₀ dot arrays, which had a large magnetic anisotropy Kᵣ of 1.6×10⁷ erg/cm³ (300 K) and a low curie temperature Tᵣ of ~580 K, are favorable for thermally assisted magnetic recording media. In the development of high performance and low power consumption storage systems, we demonstrated that the power consumption in our new storage systems can be reduced half that of normal storage systems, maintaining a high data transfer rate.

[Staff]
Professor: Kazuhiisa Fujimoto Dr., Visiting Professor: Hajime Aoi Dr., Associate Professor: Takehito Shimatsu Dr., Visiting Associate Professor: Kiyoshi Yamakawa Dr., Visiting Researchers: Susumu Ogawa Dr., Hideki Saga, Masaki Yamada Dr., Hiroshi Akaize, Yuichi Osawa Dr., Hiroyasu Kataoka, Daisuke Inoue, Koji Kudo, Takeshi Ishibashi Dr., Masahiro Aono, Kenji Oba, Koji Matsushita, Masao Kubota, Technical Assistant: Miyuki Uomoto, Secretaries: Ayumi Sato, Aya Takano

[Profile]
Kazuhiisa Fujimoto received the Dr. of Engineering degree from Kyushu University in 1997. He joined Central Research Laboratory, Hitachi, Ltd., in 1987. He joined RIEC, Tohoku University in 2007. He has been engaged in research on storage system architectures.
Takehito Shimatsu received the Dr. of Engineering degree from Tohoku University. He joined RIEC in 1998. He has been engaged in research on magnetic materials and storage devices.

[Papers]
Management Office for Health and Safety
Realizing and Maintaining a Safe and Comfortable Environment to Support Research

[Research Target and Activities]

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

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

[Staff]
Manager: Michio Niwano, Professor
Deputy Manager: Yoichi Uehara, Professor
Nobuyuki Sato, Assistant Professor
Ayako Chiba, Clerk

Contact to: anzen@riec.tohoku.ac.jp
Flexible Information System Research Center
Development of Flexible Information Systems and Management of Networks

[Research Target and Activities]
Present information systems, such as today's computers are inflexible systems, since their purpose is predefined and they only provide fixed procedures and functions. However, flexible information system can perform flexible information processing adapted to human intentions and situations of its environment.

Our goal is to investigate the principles of flexible information processing through theories and experiments and establish their system construction methodology. Moreover, we also study flexible distributed systems for advanced organization, utilization, administration, and operation of scientific information. Through practical applications of above results applied to the actual network in RIEC, we have confirmed the effectiveness of our methods. To achieve the above goal, this year we have conducted the following researches:
(1) development of a distributed and scalable authentication method for large scale overlay network,
(2) development of an agent based network management system (Fig.1) and
(3) a flexible computing mechanism in biological systems.

[Staff]
(1) Steering Committee
Professor: Yôiti Suzuki, Dr., Yoshihito Toyama, Dr., Tetsuo Kinoshita, Dr., Masafumi Shirai Dr., Atsushi Ohori, Dr., Takuo Suganuma, Dr.
(2) FIR Committee
Professor: Yoshihito Toyama, Dr., Takuo Suganuma, Dr.
Associate Professor: Takahito Aoto, Dr., Yukio Iwaya, Dr., Gen Kitagata, Dr.
Assistant Professor: Masato Yoshida, Dr., Takeshi Onomi, Dr., Kazuto Sasai, Dr.
Technical Official: Masahiko Sato
Research Fellow: Johan Sveholm Dr.
Technical Support Member: Midori Suzuki, Sachiko Nagase
(3) Regular Staff
Associate Professor: Gen Kitagata, Dr.
Assistant Professor: Kazuto Sasai, Dr.
Technical Official: Masahiko Sato
Research Fellow: Johan Sveholm Dr.
Technical Support Member: Midori Suzuki, Sachiko Nagase

[Profile]
Refer to the Advanced Acoustic Information Systems Laboratory for the profile Prof. Yôiti Suzuki.
Refer to the Computing Information Theory Laboratory for the profile Prof. Yoshihito Toyama.

[Papers]

Contact to Associate Professor Gen Kitagata : minatsu@fir.riec.tohoku.ac.jp
[Research Target and Activities]

The Fundamental Technology Center provides a wide range of technical support for research activities at the institute through the following four divisions: machine shop, evaluation, process, and software technology. Transferring highly established skills of senior staffs to the younger generation has also been promoted to maintain the present service level of the center. The activities of the present year are summarized as follows.

1. Machine Shop Division

The Machine Shop Division has been developed various novel machining methods last over forty years. On the basis of such high-level techniques, this division can supply machining products just fitting to individual special requests from researchers. In this year, 191 of fabrications were requested. 22 of them were from researches belonging to other institutes.

2. Evaluation Division

The evaluation division provides various evaluation and measurement apparatuses for shared usage. In this year, 16 laboratories utilized them and the utilization time was 2938 hours in total. Glass machining and supply of liquid nitrogen are also covered by this division. There were 15 requests to the Glass machining and 3787 litters of liquid nitrogen were supplied this year.

3. Process Division

The processing division is, in cooperation with the evaluation division, responsible for operating and maintaining the project clean room (PCR), a clean room for shared usage, along with apparatuses for processing equipped. In this year, this clean room was utilized by 11 laboratories. In addition, customized optical filters in the visible and infrared spectral range can be produced by this division, and were supplied to four laboratories this year.

4. Software Technology Division

The Software Technology Division has operated and maintained, in cooperation with Flexible Information System Research Center, local area networks in the institute.

[Staff]

Director (Professor): Yoichi Uehara
Assistant Professor: Nobuyuki Sato
Technical Official: Fumitaka Saito, Katsumi Sagae, Koichi Shoji, Tamotsu Suenaga, Ryutaro Sasaki, Maho Abe, Masahiko Sato, Keisuke Sato, Kento Abe, Hiroshi Watanabe, Munetomo Sugawara, Ryuji Yonezawa, Yuji Konno, Sadao Tsuchida, Choichi Takyu, Shigeto Agatsuma
4. Nation-wide Cooperative Research Projects

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

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

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

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

Outline of the Operation Policy

- Director
- Advisory Council
- Cooperative Research Projects Committee
  - Act as a planning center for all operations in cooperative projects research
- Cooperative Projects Selection Committee
  - Rating of applications
  - Adoption decision
- Cooperative Projects Steering Committee
  - Budget allocation
  - Daily routine business

Type A

Type B

Type S
# Nation-wide Cooperative Research Projects list 2011

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<td>Jun'ichi Murota</td>
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### Project Number | Research Project Theme | Project Leader | Facilitator in RIEC
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H23/A05 | Study on the influence of hetero-interface on the electrical characteristics of ultrathin hetero-epitaxial layers | Toshiaki Tsuchiya | Jun-ichi Murota
Shimane University Interdisciplinary Faculty of Science and Engineering
H23/A06 | Heterogeneous Network Roaming Technology for Dependable Air | Noriharu Suematsu | Noriharu Suematsu
Research Institute of Electrical Communication Tohoku University
H23/A07 | Spatial Perception and Multisensory Integration | Souta Hidaka | Yukio Iwaya
Rikkyo University College of Contemporary Psychology
H23/A08 | Signal transduction of the artificial neuronal network | Haruyuki Kamiya | Michio Niwano
Hokkaido University Graduate School of Medicine School of Medicine
H23/A09 | A research on flexible, printable organic heterojunction photovoltaic devices | Fumihiko Hirose | Michio Niwano
Faculty of Engineering. Yamagata University
H23/A10 | Development of magnetic devices using thin film element with inclined stripe magnetic domain and its applications | Hiroaki Kikuchi | Kazush Iahiyama
Iwate University
H23/A11 | Research on Infrastructure System for Cyber-Physical Integrated Society | Hiroshi Shigeno | Gen Kitagata
Keio University Science and Technology
H23/A12 | Two-dimensional sound localization based on a monaural input signal | Masashi Itoh | Yōiti Suzuki
Tohoku Institute of Technology
H21/B01 | Fundamental characteristics and applications of innovative functional field generated by various plasma flow | Akira Ando | Maki Suemitsu
Graduate School of Engineering Tohoku University
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<td>Kazuhiro Sakamoto</td>
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<td>H22/B07</td>
<td>Challenge and Perspective for Millimeter Wave Applications</td>
<td>Yohei Ishikawa</td>
<td>Noriharu Suematsu</td>
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<tr>
<td>H22/B08</td>
<td>Investigation of Bio-inspired Information Theory and its Technological Application</td>
<td>Daisuke Uragami</td>
<td>Kazuto Sasai</td>
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<tr>
<td>H22/B09</td>
<td>Study on visual information of material surface properties</td>
<td>Katsunori Okajima</td>
<td>Ichiro Kuriki</td>
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<tr>
<td>H22/B10</td>
<td>Program Verification with Mathematical Logic</td>
<td>Masahiko Sato</td>
<td>Yoshihito Toyama</td>
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<tr>
<td>H22/B11</td>
<td>Development and Application of Synthetic Aperture Radar System for Civilian Use</td>
<td>Atsushi Mase</td>
<td>Hiroshi Yasaka</td>
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<tr>
<td>H23/B01</td>
<td>Research for MEMS / high-frequency devices with nano-structured magnetic materials for advanced communications equipments</td>
<td>Makoto Sonehara</td>
<td>Kazushi Ishiyama</td>
</tr>
<tr>
<td>Project Number</td>
<td>Research Project Theme</td>
<td>Project Leader</td>
<td>Facilitator in RIEC</td>
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<td>H23/B02</td>
<td>Research on the new concept large scale memory and its system with integration of nano materials on silicon technology</td>
<td>Heiji Watanabe Graduate School of Engineering, Osaka University</td>
<td>Tetsuo Endo</td>
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<tr>
<td>H23/B03</td>
<td>Research on nano semiconductor materials and nano structured devices required for future electronic systems</td>
<td>Kikuo Yamabe Graduate School of Pure and Applied Sciences Tsukuba University</td>
<td>Tetsuo Endo</td>
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<tr>
<td>H23/B04</td>
<td>New Technologies for Reducing Iron Loss of Electrical Steels</td>
<td>Kazushi Ishiyama Research Institute of Electrical Communication Tohoku University</td>
<td>Kazushi Ishiyama</td>
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<tr>
<td>H23/B05</td>
<td>Study of functional piezoelectric materials and applications to advanced communication devices</td>
<td>Jun-ichi Kushibiki Graduate School of Engineering Tohoku University</td>
<td>Yasuo Cho</td>
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<tr>
<td>H23/B07</td>
<td>Research on Next-generation Peta-byte Information Storage</td>
<td>Hiroaki Muraoka Research Institute of Electrical Communication Tohoku University</td>
<td>Hiroaki Muraoka</td>
</tr>
<tr>
<td>H23/B08</td>
<td>Passive/Active Circuit Technologies and Their Applications for Next Generation RFIC</td>
<td>Toshio Ishizaki Faculty of Science And Technology. Ryokoku University</td>
<td>Noriharu Suematsu</td>
</tr>
<tr>
<td>H23/B09</td>
<td>Multisensory integration involving self-body motion</td>
<td>Kenzo Sakurai Faculty of liberal arts. Tohoku Gakuin University</td>
<td>Yōiti Suzuki</td>
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<tr>
<td>H23/B10</td>
<td>Next Generation Human Interface for Interactive Contents</td>
<td>Yoshifumi Kitamura Research Institute of Electrical Communication Tohoku University</td>
<td>Yoshifumi Kitamura</td>
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<tr>
<td>Project Number</td>
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<tr>
<td>H23/B11</td>
<td>Foundation of Dependable Cloud System with a Highly Reliable Programming Language System</td>
<td>Kazuhiko Kato Graduate School of Systems and Information Engineering Tsukuba University</td>
<td>Atsushi Ohhori</td>
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<tr>
<td>H21/S01</td>
<td>Information processing and communication system based on an innovative new concept associated with human functions</td>
<td>Masayuki Numao The Institute of Scientific and Industrial Research (ISIR) Osaka University</td>
<td>Masafumi Shirai</td>
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<tr>
<td>H23/S01</td>
<td>Development of essential technologies directed to systematization of superhivision</td>
<td>Hidenori Mimura Shizuoka University Research Institute of Electronics</td>
<td>Yōiti Suzuki</td>
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<tr>
<td>H23/S02</td>
<td>Spintronics International Alliance</td>
<td>Kohei Itoh Keio University Science and Technology</td>
<td>Hideo Ohno</td>
</tr>
<tr>
<td>H23/S03</td>
<td>Collaborative Research on Nano-electronics</td>
<td>Tetsuya Osaka Waseda Univ. Institute for Nanoscience &amp; Nanotechnology</td>
<td>Michio Niwano</td>
</tr>
</tbody>
</table>
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

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<tr>
<th>Title</th>
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<tbody>
<tr>
<td>1. Quantum Electronics of Light Waves and Micro Waves</td>
<td>Feb. 6-8, 1964</td>
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<tr>
<td>2. Ultra-High Frequency Acoustoelectronics</td>
<td>Feb.11-12, 1965</td>
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<tr>
<td>3. Artificial Intelligence</td>
<td>Mar. 8-9, 1966</td>
</tr>
<tr>
<td>8. Speech Information Processing</td>
<td>Feb.24-26, 1971</td>
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<tr>
<td>10. Liquid Crystals · Their Molecular Orientations and Application to Display Devices</td>
<td>Dec.13-14, 1974</td>
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<td>12. The Memorial Symposium on the 40th Anniversary of the Foundation of RIEC</td>
<td>Sep.25-26, 1975</td>
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<td>14. Stoichiometry of Compound Crystals</td>
<td>Nov.24-25, 1977</td>
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<tr>
<td>15. Submillimeter Waves</td>
<td>Nov.16-17, 1978</td>
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<td>17. Graph Theory and Algorithms</td>
<td>Oct.24-25, 1980</td>
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<td>18. Perpendicular Magnetic Recording</td>
<td>Mar.11-12, 1982</td>
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<tr>
<td>20. Plasma Non-Linear Phenomena · Basic Problems for Fusion Plasmas</td>
<td>Mar. 8-9, 1984</td>
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<tr>
<td>29</td>
<td>Perspective for New Computing Paradigm</td>
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<td>30</td>
<td>Current Status and Future Prospects of System Control</td>
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<td>Photo-and Plasma-Excited Processes on Surfaces</td>
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<td>Nano Spinics and Power Electronics</td>
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<td>36</td>
<td>Potential Formation and Related Nonlinear Phenomena in Plasmas</td>
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<td>37</td>
<td>New Trend in Ultrasonic Measurements</td>
</tr>
<tr>
<td>Title</td>
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<tr>
<td>Intrinsic Josephson Effect and THz Plasma Oscillation in High $T_c$ Superconductors</td>
<td>Feb.23-25, 1997</td>
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<tr>
<td>The International Joint Conference on Silicon Epitaxy and Heterostructures</td>
<td>Sep.13-17, 1999</td>
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<tr>
<td>International Workshop on Photonic and Electromagnetic Crystal Structures</td>
<td>Mar.8-10, 2000</td>
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<tr>
<td>New Paradigm VLSI Computing</td>
<td>Dec.12-14, 2002</td>
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<tr>
<td>3rd International Workshop on New Group IV (Si-Ge-C) Semiconductors</td>
<td>Oct.12-13, 2004</td>
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<tr>
<td>3rd International Workshop on High Frequency Micromagnetic Devices and Materials (MMDM3)</td>
<td>Apr.11-12, 2005</td>
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<tr>
<td>4th International Conference on Silicon Epitaxy and Heterostructures (ICSl-4)</td>
<td>May 23-26, 2005</td>
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<tr>
<td>1st International Workshop on New Group IV Semiconductor Nanoelectronics</td>
<td>May 27-28, 2005</td>
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<tr>
<td>The 1st RIEC International Workshop on Spintronics -Spin Transfer Phenomena-</td>
<td>Feb.8-9, 2006</td>
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<tr>
<td>4th International Workshop on High Frequency Micromagnetic Devices and Materials (MMDM4)</td>
<td>May 8, 2006</td>
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<tr>
<td>2nd RIEC International Workshop on Spintronics</td>
<td>Feb.15-16, 2007</td>
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<tr>
<td>Japan-China Joint Conference on acoustics, JCA2007</td>
<td>Jun.4-6, 2007</td>
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<td>23</td>
<td>The 3rd RIEC International Workshop on Spintronics</td>
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<td>24</td>
<td>3rd International Workshop on New Group IV Semiconductor Nanoelectronics</td>
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<tr>
<td>25</td>
<td>International Workshop on Nanostructures &amp; Nanoelectronics</td>
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<tr>
<td>27</td>
<td>International Interdisciplinary-Symposium on Gaseous and Liquid Plasmas (ISGLP 2008)</td>
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<td>29</td>
<td>The 4th RIEC International Workshop on Spintronics</td>
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<td>31</td>
<td>Mini R.I.E.C. workshop on multimodal perception</td>
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<tr>
<td>32</td>
<td>The 4th International Symposium on Ultrafast Photonic Technologies</td>
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<tr>
<td>34</td>
<td>2nd RIEC-CNSI Workshop on Nanoelectronics,Spintronics and Photonics (5th RIEC Symposium on Spintronics)</td>
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<td>36</td>
<td>5th International Workshop on New Group IV Semiconductor Nanoelectronics</td>
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<td>37</td>
<td>6th RIEC International on Spintronics</td>
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<tr>
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<td>2nd International Workshop on Nanostructure &amp; Nanoelectronics</td>
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<td>12th International Multisensory Research Forum (IMRF2011)</td>
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<td>The 8th RIEC International Workshop on Spintronics</td>
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<tr>
<td>45</td>
<td>The Sixth International Symposium on Medical, Bio- and Nano-Electronics</td>
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</table>
6. Study Groups on Electrical Communication

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

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

| Electromagnetic and Optical Waves Engineering |
| Chair          | Prof. Kunio Sawaya |
| Manager        | Associate Prof. Qiang Chen |

| Acoustic Engineering |
| Chair          | Prof. Akinori Ito |
| Manager        | Associate Prof. Yukio Iwaya |

| Sendai "Plasma Forum" |
| Chair          | Prof. Rikizo Hatakeyama |
| Manager        | Prof. Akira Ando |

| Sendai Seminar on EMC |
| Chair          | Prof. Hideaki Sone |
| Manager        | Prof. Masahiro Yamaguchi |
## Computer Science

<table>
<thead>
<tr>
<th>Role</th>
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<tbody>
<tr>
<td>Chair</td>
<td>Prof. Ayumi Shinohara</td>
</tr>
<tr>
<td>Manager</td>
<td>Associate Prof. Eijiro Sumii</td>
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</tbody>
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## Systems Control

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<tr>
<td>Chair</td>
<td>Prof. Makoto Yoshizawa</td>
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<td>Manager</td>
<td>Associate Prof. Noriyasu Homma</td>
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## Information-bitronics

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<tr>
<td>Chair</td>
<td>Prof. Michio Niwano</td>
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<td>Prof. Tatsuo Yoshinobu</td>
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## Spinics

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<tr>
<td>Chair</td>
<td>Prof. Hiroaki Muraoka</td>
</tr>
<tr>
<td>Manager</td>
<td>Associate Prof. Kenji Nakamura</td>
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<tr>
<td>Manager</td>
<td>Assistant Prof. Kousaku Miyake</td>
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## New Paradigm Computing

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<tr>
<td>Chair</td>
<td>Prof. Michitaka Kameyama</td>
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<td>Associate Prof. Masahide Abe</td>
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## Ultrasonic Electronics

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<tr>
<td>Chair</td>
<td>Prof. Hiroshi Kanai</td>
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<tr>
<td>Manager</td>
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<tr>
<td><strong>Brainware</strong></td>
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<td>Chair</td>
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<tr>
<td>Prof. Koji Nakajima</td>
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<td>Associate Prof. Shigeo Sato</td>
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<tr>
<th><strong>Mathematical Physics and its Application to Information Sciences</strong></th>
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<td>Prof. Kazuyuki Tanaka</td>
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<td>Prof. Kazuyuki Tanaka</td>
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<th><strong>Biocybernetics and Bioinformatics</strong></th>
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<tr>
<td>Prof. Satoshi Shioiri</td>
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<tr>
<td>Manager</td>
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<tr>
<td>Assistant Prof. Takeshi Obayashi</td>
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<td>Prof. Junichi Murota</td>
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<td>Associate Prof. Masao Sakuraba</td>
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<td>Prof. Tetsuo Kinoshita</td>
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<tr>
<td>Manager</td>
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<tr>
<td>Prof. Takuo Suganuma</td>
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</tbody>
</table>
7. International Activities

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

**International academic exchange programs:**

- The Institute of Physics, Polish Academy of Sciences (Poland)
- The Faculty of Science, Chulalongkorn University (Thailand)
- Harbin Institute of Technology (China)
- The James Frank Institute, The University of Chicago (U.S.A.)
- Queen Mary and Westfield College, University of London (U.K.)
- Scientific Research Department, Shenzhen University (China)
- Institute of Information and Communication Technology, Sung-Kyung-Kwan University (Korea)
- Institute of Materials Science, Faculty of Applied Physics, University of Twente (Netherlands)
- The Institute of Radioengineering and Electronics Russian Academy of Sciences (Russia)
- Department of Electronics Science and Engineering, University of Nanjing (China)
- School of Computer and Communication Engineering, Taegu University (Korea)
- The Interdisciplinary Center on Nanoscience of Marseille, National Center of Scientific Research (France)
- IHP-Innovations for High Performance microelectronics (Germany)
- Institute of Semiconductors Chinese Academy of Sciences (China)
- WINLAB, Rutgers University (U.S.A.)
- University of Vigo (Spain)
- State University of New York (U.S.A.)

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

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<td>IEICE Electronics Express</td>
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<td>5</td>
<td>IEICE Trans. on Electronics</td>
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<td>6</td>
<td>Interdisciplinary Information Science</td>
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<tr>
<td>7</td>
<td>International Journal of Artificial Intelligence, Neural Networks, and Complex Problem Solving Technologies</td>
</tr>
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<td>8</td>
<td>International Journal of Computer Science and Network Security</td>
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<tr>
<td>9</td>
<td>International Journal of Energy, Information and Communications</td>
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<td>10</td>
<td>International Journal of Information Sciences and Computer Engineering (IJISCE)</td>
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<td>11</td>
<td>Journal of Ambient Intelligence and Humanized Computing</td>
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<td>Nonlinear Theory and Its Applications, IEICE</td>
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**Recent international conferences programmed by a staff in RIEC:**

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<td>10th Asia Pacific Conference on Computer Human Interaction (APCHI2012)</td>
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<td>3</td>
<td>15th International Symposium on the Physics of Semiconductors and Applications (ISPSA)</td>
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<td>4</td>
<td>16th OptoElectronics and Communications Conference (OECC2011)</td>
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<td>5</td>
<td>2011 Conference on Lasers and Electro-Optics (CLEO2011)</td>
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<td>6</td>
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<td>7</td>
<td>2012 Conference on Lasers and Electro-Optics (CLEO2012)/Technical Program Committee Member</td>
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<td>2nd CSIS International Symposium on Spintronics-based VLSIs and 8th RIEC International Workshop on Spintronics</td>
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<td>11</td>
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<td>6th International School and Conference on Spintronics and Quantum Information Technology (SPINTECH6)</td>
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<td>ACM Symposium on Virtual Reality Software and Technology (VRST)</td>
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<td>14</td>
<td>ACSIN: 11th International Conference on Atomically Controlled Surfaces, Interfaces and Nanostructures</td>
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<td>15</td>
<td>Asia Pacific Microwave Conference (APMC)</td>
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<td>16</td>
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<td>CIMTC: 4th International Conference on Smart Materials, Structures and Systems</td>
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<tr>
<td>22</td>
<td>IEEE International Symposium on Asynchronous Circuits and Systems</td>
</tr>
<tr>
<td>23</td>
<td>IEEE International Symposium on Multiple-Valued Logic</td>
</tr>
<tr>
<td>24</td>
<td>IEEE Symposium on 3D User Interfaces (3DUI)</td>
</tr>
<tr>
<td>25</td>
<td>International Multisensory Research Forum (IMRF) 2011</td>
</tr>
<tr>
<td>26</td>
<td>International Multisensory Research Forum (IMRF) 2012</td>
</tr>
<tr>
<td>27</td>
<td>International Quantum Electronics (IQEC), Program Subcommittee Member for Quantum Information</td>
</tr>
<tr>
<td>28</td>
<td>International Symposium on Nonlinear Theory and its Applications</td>
</tr>
<tr>
<td>29</td>
<td>ISCS: International Symposium on Compound Semiconductors</td>
</tr>
<tr>
<td>30</td>
<td>Joint Polish-Japanese Workshop, Spintronics-from NewMaterials to Applications</td>
</tr>
<tr>
<td>31</td>
<td>OTST: Int. Conf on Optical Terahertz Science and Technology</td>
</tr>
<tr>
<td>32</td>
<td>SPIE International Conference on Defense, Security, and Sensing</td>
</tr>
<tr>
<td>33</td>
<td>SPIE Photonics West, Physics and Simulation of Optoelectronic Devices</td>
</tr>
<tr>
<td>34</td>
<td>The 11th IEEE International Conference on Cognitive Informatics and Cognitive Computing (ICCI* CC 2012)</td>
</tr>
<tr>
<td>35</td>
<td>The 15th International Conference on Network-Based Information Systems (NBiS·2012)</td>
</tr>
<tr>
<td>36</td>
<td>The 1st International Workshop on Smart Technologies for Energy, Information and Communication (STEIC2012)</td>
</tr>
<tr>
<td>37</td>
<td>The 2012 IEEE/WIC/ACM Intern. Joint Conference on Web Intelligence and Intelligent Agent Technology (WI-IAT 2012)</td>
</tr>
<tr>
<td></td>
<td>The 5th International Symposium on Adaptive Motion of Animals and Machines</td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>40</td>
<td>TWHM: Topical Workshop on Heterostructure Microelectronics</td>
</tr>
</tbody>
</table>
8. Periodicals Published by the Institute

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

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

This journal aims at providing an opportunity to publish research results of the Institute as well as the result of the Departments of Electrical Engineering, Communication Engineering, Electronics Engineering, and Information Engineering of the Faculty of Engineering. Since the journal also aims at publishing general research activities of the Institute and of the Departments such as records of the final lectures of retiring professors, records of the Institute Symposium, and reviews.

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

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

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

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

3. RIEC News

With the 75th anniversary of the establishment of RIEC, RIEC News introduces cutting-edge's
research and the vision of the future from RIEC’s contributions to the progression of science and technology in Japan. Since the launch in March 2011 to March 2012, four issues have been published. Every issue introduces special topics such as large scale projects and the establishment of the Research Organization of Electrical Communication (ROEC), etc. RIEC News also includes current information about each laboratory and center, all kinds of RIEC events, research exchange meetings, laboratories open to the public (RIEC Open Day), etc. Further, RIEC News offers a notification service by mail whenever a new issue is released and an electronic version of every issue published so far can be downloaded by following the link below.

http://www.riec.tohoku.ac.jp/riecnews/
9. Staff, Land and Buildings, Budget

1. Staff

<table>
<thead>
<tr>
<th>Classification</th>
<th>Division</th>
<th>Laboratory for Nanoelectronics and Spintronics</th>
<th>Laboratory for Brainware Systems</th>
<th>Research Center for 21st century Information Technology</th>
<th>Fundamen tal Technology Center</th>
<th>Administration Office</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professors</td>
<td>19</td>
<td>3</td>
<td>3</td>
<td>25</td>
<td></td>
<td></td>
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<tr>
<td>Associate Professors</td>
<td>15</td>
<td>3</td>
<td>3</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Assistant Professors</td>
<td>15</td>
<td>3</td>
<td>6</td>
<td>24</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Research Fellows</td>
<td>10</td>
<td>2</td>
<td>1</td>
<td>22</td>
<td></td>
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<tr>
<td>Technical Officials</td>
<td></td>
<td></td>
<td>15</td>
<td>1</td>
<td>14</td>
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<tr>
<td>Administrative Officials</td>
<td></td>
<td></td>
<td>16</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>68</td>
<td>11</td>
<td>10</td>
<td>13</td>
<td>119</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Land and Buildings

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

<table>
<thead>
<tr>
<th>Name of Buildings</th>
<th>Structure</th>
<th>Year of Completion</th>
<th>Floor Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building No.1</td>
<td>Reinforced Concrete, 4 floors</td>
<td>Building: S 1962, 1963</td>
<td>7,772m²</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Building: N 1969</td>
<td>7,085m²</td>
</tr>
<tr>
<td>Building No.2</td>
<td>Reinforced Concrete, 4 floors</td>
<td>1962, 1983</td>
<td>7,085m²</td>
</tr>
<tr>
<td>Laboratory for Nanoelectronics and Spintronics</td>
<td>Steel-frame, 5 floors</td>
<td>2004</td>
<td>7,375m²</td>
</tr>
<tr>
<td>Research Center for 21st century Information Technology</td>
<td>Reinforced Concrete, 3 floors</td>
<td>1950</td>
<td>1,343m²</td>
</tr>
<tr>
<td>Evaluation and Analysis Center</td>
<td>Reinforced Concrete, 2 floors</td>
<td>1981</td>
<td>790m²</td>
</tr>
<tr>
<td>Helium Sub-Center</td>
<td>Reinforced Concrete(partly light-weight steel-flame), 1 floor</td>
<td>1972</td>
<td>166m²</td>
</tr>
<tr>
<td>Machine Shop</td>
<td>Reinforced Concrete(partly light-weight steel-flame), 1 floor</td>
<td>1965, 1966, 1978</td>
<td>470m²</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td>508m²</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>28,776m²</td>
</tr>
</tbody>
</table>

3. Budget

(Unit: 1,000yen)

<table>
<thead>
<tr>
<th>Financial Year</th>
<th>Personnel Expenditure</th>
<th>Supplies Expenditure</th>
<th>Ministry of Education, Science and Culture</th>
<th>Partnership Between Universities and Industry</th>
<th>Leading-edge Research Promotion Fund</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>976,961</td>
<td>813,724</td>
<td>700,615</td>
<td>888,833</td>
<td>0</td>
<td>3,374,133</td>
</tr>
<tr>
<td>2008</td>
<td>879,481</td>
<td>953,005</td>
<td>694,883</td>
<td>1,069,832</td>
<td>0</td>
<td>3,597,186</td>
</tr>
<tr>
<td>2009</td>
<td>1,026,511</td>
<td>1,562,318</td>
<td>605,100</td>
<td>798,053</td>
<td>400,440</td>
<td>4,392,422</td>
</tr>
<tr>
<td>2010</td>
<td>777,776</td>
<td>735,496</td>
<td>418,680</td>
<td>962,712</td>
<td>1,034,827</td>
<td>3,929,491</td>
</tr>
<tr>
<td>2011</td>
<td>835,898</td>
<td>1,174,027</td>
<td>469,840</td>
<td>1,122,944</td>
<td>813,777</td>
<td>4,416,486</td>
</tr>
</tbody>
</table>
10. Afterword

These days, one often hears it said that it is important for a university to establish a distinctive character. While this may be achieved in a variety of ways, I believe the existence of affiliated research institutes carries considerable weight, as their activities, developed over many years, are deeply rooted in the university’s traditions and culture. Further, it is a key task of these research institutes to lay the foundation of the next-generation information industry through technological development firmly rooted in the depth of knowledge that only a university can provide.

From its early work with weak currents, RIEC began life as a primarily device-oriented research laboratory; we have since added software technologies, and today our integrated research covers the whole range from materials to information services. Most recently, utilizing the perspective offered by information and communications, we are undertaking cutting-edge research and development in areas as diverse as artificial hearts and the movements of living organisms. To further our collaborative research, we also hold a series of research exchange meetings to improve contact among RIEC's nearly thirty laboratories, with the aim of overcoming compartmentalization among the four Research Divisions and the individual institutes and centers and thus creating new R & D partnerships and synergies. Readers of this Annual Report will see signs of these initiatives beginning to germinate. The report also includes the results of the Support Program for Creative Research for young researchers, which I trust will be of interest.

We would be delighted to receive feedback from readers of this Report. Perhaps the contents do not reflect our new direction as well as we hoped? Or perhaps you would like to suggest some interesting new line to pursue. All comments will be greatly appreciated, and I look forward to your continuing support and encouragement.