RIEC

Annual Report 2011

Research Institute of Electrical Communication, Tohoku University

Annual Report of Research Institute of Electrical Communication 2011

Contents

1. Preface

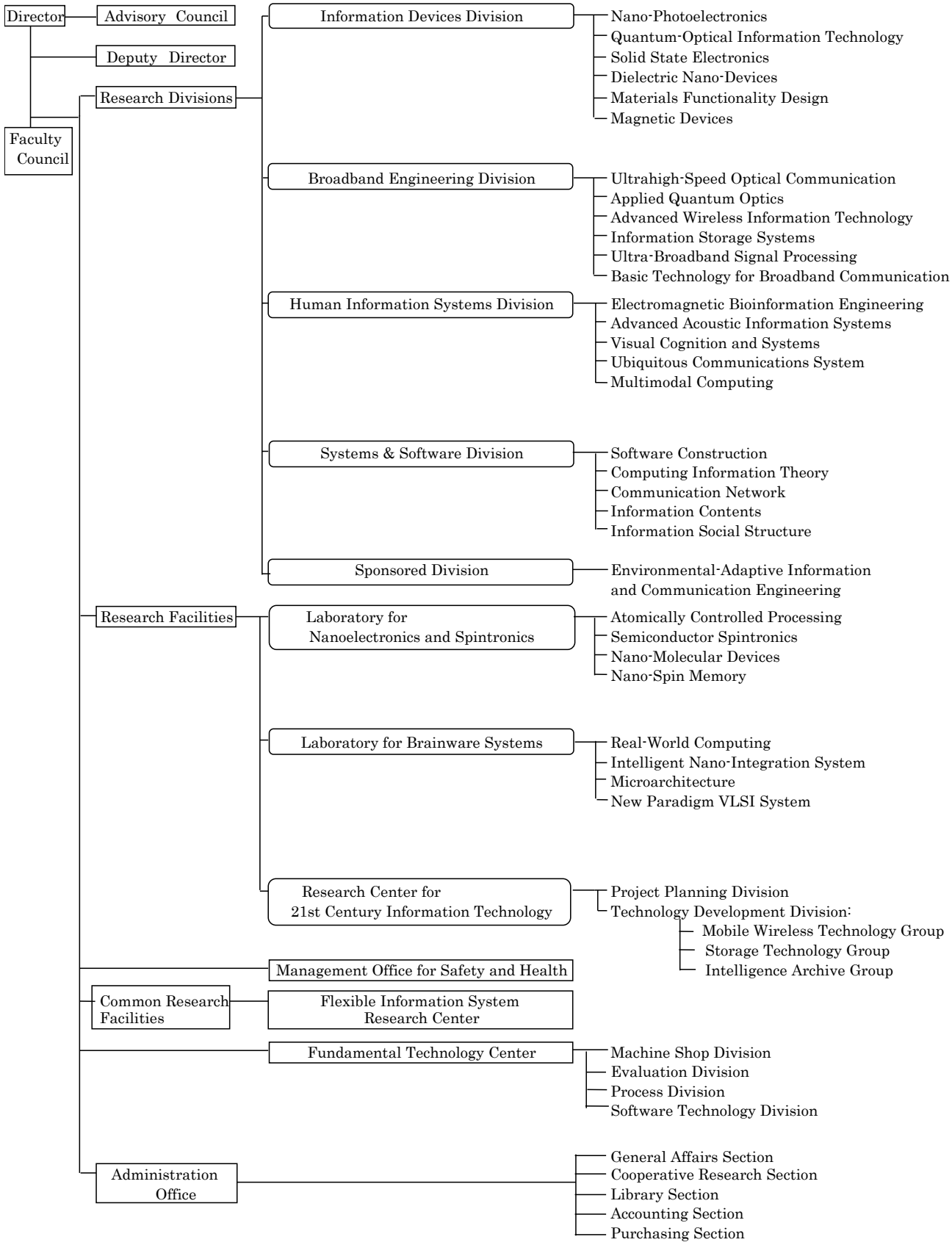
On behalf of the Research Institute of Electrical Communication (RIEC) of Tohoku University, I would like to express my gratitude for the kind and unfailing support our work receives. I invite you all to read this report of RIEC's research activities in fiscal 2011 and to give us your opinions and comments.

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



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 resolution by STM light emission spectroscopy. STM light emission spectroscopy combined with ps laser pulse irradiation to the STM gap was carried out for Sb_2Te_3. Fine structures originating from phonon-electron interactions were found in the STM light emission spectra, showing that one can investigate phonon properties 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.

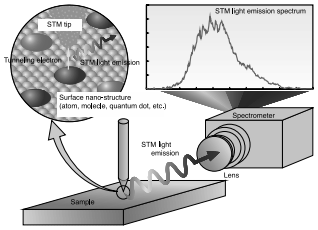


Fig. 1 STM light emission spectroscopy

[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]

[1] W. Iida, J. Ahamed, S. Katano, and Y. Uehara, "Mechanism of Prism-Coupled Scanning Tunneling Microscope Light Emission", Jpn. J. Applied Phys. **50**, 095201 (2011).

[2] S. Katano and Y. Uehara, "Nanoscale properties of single atoms and molecules investigated by scanning tunneling microscope light emission spectroscopy", OYO BUTURI **80**, 960 (2011). (in Japanese)

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Quantum-Optical Information Technology

Development of optoelectronic devices for quantum information and communication technology

Quantum-Optical Information Technology: Keiichi Edamatsu, Professor
Quantum 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.

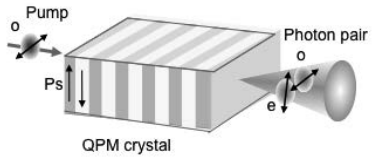


Fig. 1 Entangled photon generation using quasi-phase matching and extended phase matching.

[Staff]

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

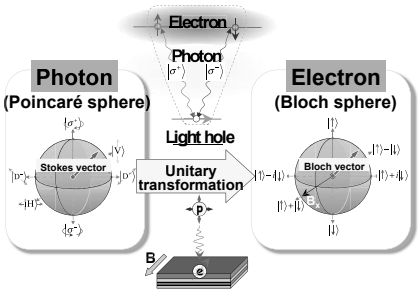


Fig. 2 Quantum media conversion from photon polarization to an electron spin.

[Profile]

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

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

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

[Papers]

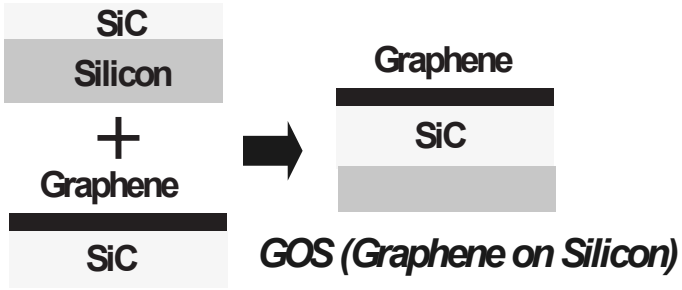
[1] Y. Mitsumori, Y. Miyahara, K. Uedaira, H. Kosaka, S. Shimomura, S. Hiyamizu, and K. Edamatsu, "Micro-pump-probe spectroscopy of an exciton in a single semiconductor quantum dot using a heterodyne technique," Jpn. J. Appl. Phys. **50**, 095004/1-4 (2011)
[2] T. Inagaki, H. Kosaka, Y. Mitsumori, and K. Edamatsu, "Electron spin state tomography with coherent Kerr effect," Appl. Phys. Lett. **99**, 173108/1-3 (2011)
[3] W. Ueno, F. Kaneda, H. Suzuki, S. Nagano, A. Syouji, R. Shimizu, K. Suizu, and K. Edamatsu, "Entangled photon generation in two-period quasi-phase-matched parametric down-conversion," Optics Express **20**, 5508-5517 (2012)

Solid State Electronics Laboratory

Paving a Way for Introducing Graphene into Silicon Technology

Solid State Electroncis Maki Suemitsu, Professor

[Research Target and Activities]



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

In 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 enginnering (1975), Ph.D on electronic engineering (1980). He started his service at Research Institute of Electrical Communication (RIEC) as research associate (1980), and became associate professor (1990). He then became professor at Center for Inderdisciplinary Research (2003). Since 2008, he has been professor at RIEC. He has been engaged mainly on surfaces of semiconductor thin fims. He was awarded the 30 th Kumagai prize of the best paper from the Vacuum Soceity of Japan (2005) and the Best Paper Award from the Surface Science Society of Japan (2011).

[Papers]

[1] M.-H. Jung, H. Handa, et al., "Investigation of Graphene Field Effect Transistors with Al_2O_3 Gate Dielectrics Formed by Metal Oxidation", Jpn. J. Appl. Phys., Vol. 50, No. 7, pp. 070111-1-5, 2011.
[2] H. Fukidome, R. Takahashi, S. Abe et al., "Control of epitaxy of graphene by crystallographic orientation of a Si substrate toward device applications", J. Mater. Chem., Vol. 21, pp. 17242-17248, 2011.
[3] H. Fukidome, S. Abe et al., "Controls over Structural and Electronic Properties of Epitaxial Graphene on Silicon using Surface Termination of 3C-SiC(111)/Si", Appl. Phys. Express, Vol. 4, pp.115104-1-3, 2011

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Dielectric Nano-Devices

Research on Dielectric Nano Science and Technology

Dielectric Nano-Devices Yasuo Cho, Professor

[Research Target and Activities]

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

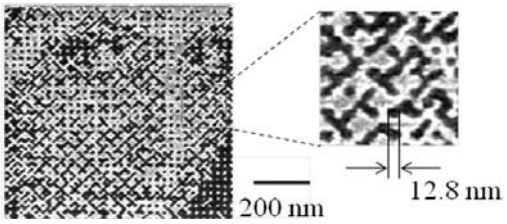

Fig.1 Digital bit data written on ferroelectric single crystal with the areal recording density of 4 Tbit/inch^2.

Major achievements of studies in 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 (7×7) 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.
Visiting Professor : Koichiro Honda, Dr.
Assistant Professor : Yoshiomi Hiranaga, Dr.
Assistant Professor : Kohei Yamasue, Dr.
Technical Official : Yasuo Wagatsuma

[Profile]

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

[Papers]

[1] Kohei Yamasue and Yasuo Cho, "Observation of Polarization Distribution on Si(111) Surface by Scanning Nonlinear Dielectric Microscopy", Jpn. J. Appl. Phys, Vol.50, pp.09NE12-1-09NE12-5, 2011.
[2] N. Chinone, K. Yamasue, Y. Hiranaga, Y. Cho, "Super Higher-Order Nonlinear Dielectric Microscopy", The 19th International Colloquium on Scanning Probe Microscopy, S6-5.P.17, 2011.
[3] Koichiro Honda and Yasuo Cho, "Visualization of Electrons Localized in Metal-Oxide-Nitride-Oxide-Semiconductor Flash Memory Thin Gate Films by Detecting High-Order Nonlinear Permittivity Using Scanning Nonlinear Dielectric Microscopy", Appl. Phys. Express, vol.5, pp.036602-1-3, 2012.

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_2MnSi/MgO/Co_2MnSi 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.

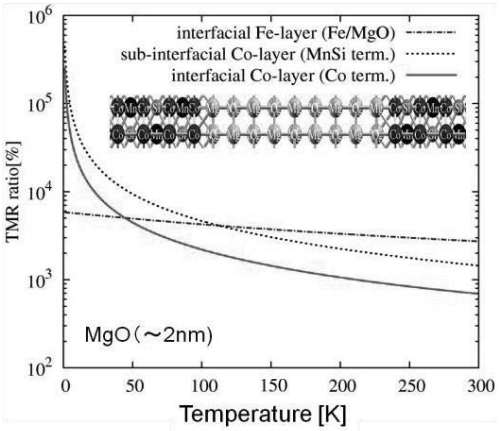

Fig. 1

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

We investigated the spin-dependent transport properties of Co_2MnSi/*X*/Co_2MnSi (*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 : Yoshio Miura, Dr.
Assistant Professor : Kazutaka Abe, Dr.
Research Fellow: Masahito Tsujikawa, Dr.

[Profile]

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

[Papers]

[1] Y. Miura, K. Abe and M. Shirai, "Effects of interfacial noncollinear magnetic structures on spin-dependent conductance in Co_2MnSi/MgO/Co_2MnSi magnetic tunnel junctions: A first-principles study," Phys. Rev. B, Vol. 83, No. 21, Article no. 214411, pp. 1-6, 2011

[2] K. Abe and N. W. Ashcroft, "Crystalline diborane at high pressures," Phys. Rev. B, Vol. 84, No.10, Article no. 104118, pp. 1-5, 2011

[3] Y. Miura, K. Futatsukawa, S. Nakajima, K. Abe and M. Shirai, "First-principles study of ballistic transport properties in Co_2MnSi/*X*/Co_2MnSi (001) (*X* = Ag, Au, Al, V, Cr) trilayers," Phys. Rev. B, Vol. 84, No. 13, Article no. 134432, pp. 1-6, 2011

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3.2 Broadband Engineering Division: Research Target and Results

In order to establish the future broadband communication systems and novel devices that are flexibly applied to the future ubiquitous ultra-large capacity information communication, research and development are carrying out over the wide bands of microwaves, millimeter/submillimeter waves, terahertz waves, and lightwaves with regard to the information generation, transmission, processing 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 $15\mathrm{p\,W}/\sqrt{\mathrm{Hz}}$ 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/inch^2, which is tenfold of current density, was difficult only by the bit-patterned media by theoretical approach with a computer simulation. For such high density, we clarified thermal assist recording technique that heats a narrow recording area is indispensable. Storage system technology to enhance the data transfer rate was also developed.

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

Synthetic aperture radars (SAR) are useful for all-weather surveillance and rescue. 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 Masataka Nakazawa, Professor
Research Area of Optical Signal Processing Toshihiko Hirooka, Associate Professor
Research Area of High Accuracy Measurements using Optical Fibers
Masato Yoshida, Associate Professor

[Research Target and Activities]

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

This year, we successfully achieved 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.

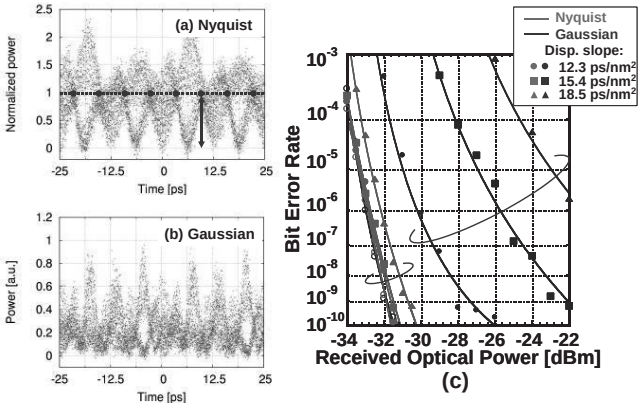


Fig. 1 Dispersion tolerance in 160 Gbaud Nyquist and conventional Gaussian pulse transmission.

[Staff]

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

[Profile]

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

[1] P. Guan, T. Hirano, K. Harako, Y. Tomiyama, T. Hirooka, and M. Nakazawa, “2.56 Tbit/s/ch polarization-multiplexed DQPSK transmission over 300 km using time-domain optical Fourier transformation,” Opt. Express, vol. 19, B567-B573, 2011.
[2] M. Nakazawa, T. Hirooka, P. Ruan, and P. Guan, "Ultrahigh-speed “orthogonal” TDM transmission with an optical Nyquist pulse train," Opt. Express vol. 20, 1129-1140, 2012.
[3] K. Kasai, D. O. Otuya, M. Yoshida, T. Hirooka, and M. Nakazawa, “Single-carrier 800-Gb/s 32 RZ/QAM coherent transmission over 225 km employing a novel RZ-CW conversion technique,” IEEE Photon. Technol. Lett., vol. 24, 416-418, 2012.

Applied Quantum Optics

Research on Innovative Highly Functional Photonic Semiconductor Devices

Highly Functional Photonics Hiroshi Yasaka, Professor

[Research Target and Activities]

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

Ultra-high-speed semiconductor photonic active devices are being investigated. 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 (V_π) 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.

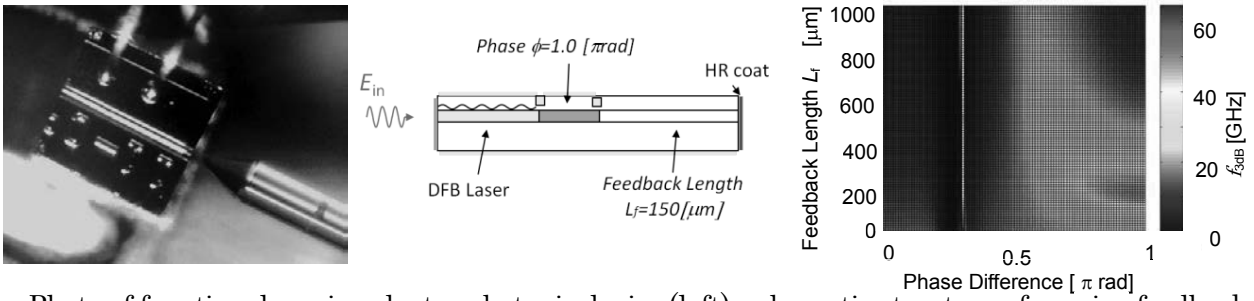


Photo of functional semiconductor photonic device (left), schematic structure of passive feedback semiconductor laser , PFL (middle), and calculated 3 dB bandwidth of the PFL as functions of feedback length and phase difference between lasing mode and feedback light.

[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]

[1] H. Ishihara, Y. Saito, W. Kobayashi, and H. Yasaka, "Bandwidth enhanced operation of single mode semiconductor laser by intensity modulated signal light injection," to be submitted to IEICE Transactions on Electronics.

Contact to Professor Hiroshi Yasaka : yasaka@riec.tohoku.ac.jp

Advanced Wireless Information Technology

For 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.

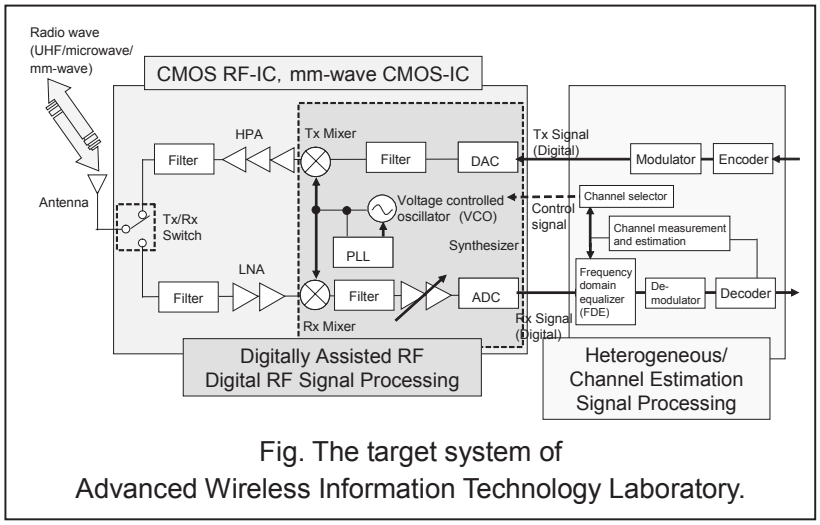


Fig. The target system of
Advanced Wireless Information Technology Laboratory.

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

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

[Staff]

Professor: Noriharu Suematsu, Ph. D
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]

[1] N. Suematsu, "Si-RFIC technologies for multi-band multi-mode wireless terminals," 2011 China-Japan Microwave Conference (CJMW), pp.1-4, China, April 2011. (Invited, Keynote)

[2] S. Kameda, H. Oguma, N. Izuka, F. Yamagata, Y. Asano, Y. Yamazaki, S. Tanifuji, N. Suematsu, T. Takagi, and K. Tsubouchi, "Proposal of heterogeneous wireless communication network with soft handover in application layer: Feasibility study based on field trial results," 6th International ICST Conference on Cognitive Radio Oriented Wireless Networks and Communications (CROWNCOM2011), Osaka, June 2011.

[2] S. Tanifuji, K. Ando, T. T. Ta, S. Kameda, N. Suematsu, T. Takagi, and K. Tsubouchi, "High sampling rate 1GS/s current mode pipeline ADC in 90nm Si-CMOS process," 2011 IEEE MTT-S International Microwave Workshop Series on Intelligent Radio for Future Personal Terminals 2011 (IMWS2011), Korea, August 2011. (Invited)

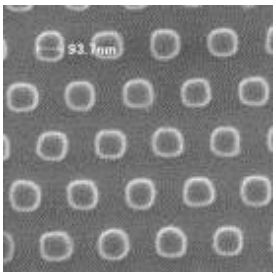
[3] N. Suematsu, S. Yoshida, S. Tanifuji, S. Kameda, T. Takagi, and K. Tsubouchi, "60GHz antenna integrated transmitter module using 3-D SiP technology and organic substrates," European. Microwave Conference (EuMC2011), Manchester, UK , October 2011. (Invited)

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]

[1] Kenji Miura, Eiji Yamamoto, Hajime Aoi, and Hiroaki Muraoka, “Off-track error probability due to track squeeze in shingled writing,” J. Appl. Phys. Vol. 109, 07B773, Apr. 2011.
[2] Simon John Greaves, Hiroaki Muraoka, and Yasushi Kanai, “The feasibility of bit-patterned recording at 4 Tb/in2 without heat-assist,” J. Appl. Phys. Vol. 109, 07B702, Apr. 2011.
[3] Koji Tsushima, Kenji Miura, Hiroaki Muraoka, “Estimation of Magnetization Transition Width and Shape by Inverse Reciprocity,” IEEE Trans. Magn., Vol. 47, No. 10, pp. 3000-3003, Oct. 2011.

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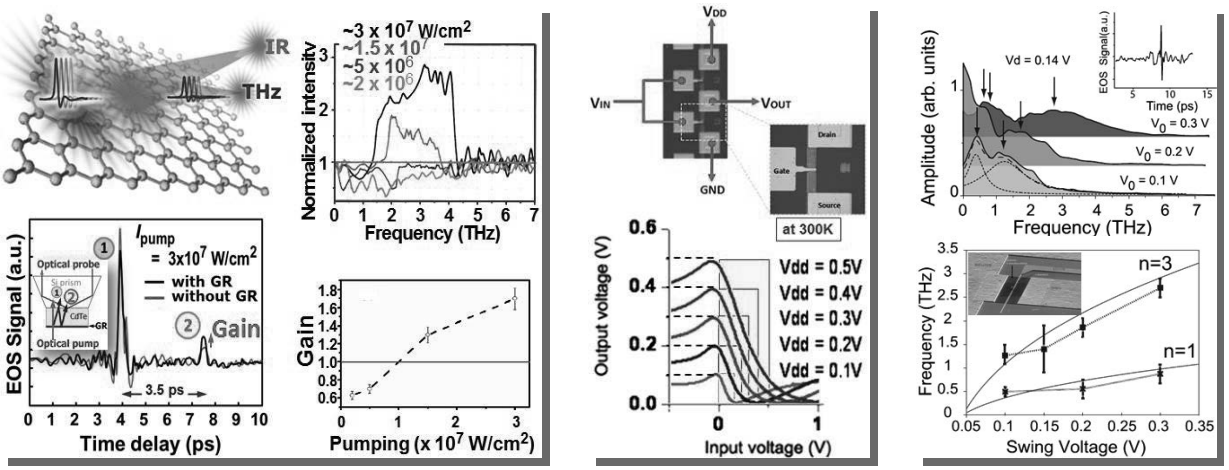
Ultra-Broadband Signal Processing

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: compliment-ary 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.

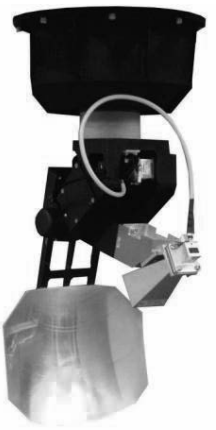
Tetsuya Suemitsu: received Dr. Eng. from Waseda Univ., Japan, in 2000. Research Scientist, NTT Labs., Japan (1994- 2006); Visiting Scientist, MIT, USA (2002-2003); Assoc. Prof., Tohoku Univ., Japan (2006-). Recipient of the Best Paper Award, IEICE (2003), and the ELEX Best Paper Award, IEICE (2007).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

[Papers]

[1] H. Karasawa, *et al.*, J. Infrared Milli. Terahertz. Waves, Vol. 32, No. 5, pp. 655-665, 2011.
[2] A. El Moutaouakil, *et al.*, Jpn. J. Appl. Phys. Vol. 50, No. 7, pp. 070113-1-4, 2011.
[3] S. Takabayashi, *et al.*, Diamond and Related Materials, Vol. 22, pp. 118-123, 2012.
[4] T. Yoshida, *et al.*, Phys. Status Solidi C, Vol. 9, No. 2, pp. 354-356, 2012.

Basic Technology for Broadband Communication

High Resolution Synthetic Aperture Radar for Civilian Applications



Live SAR
Imaging Radar

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

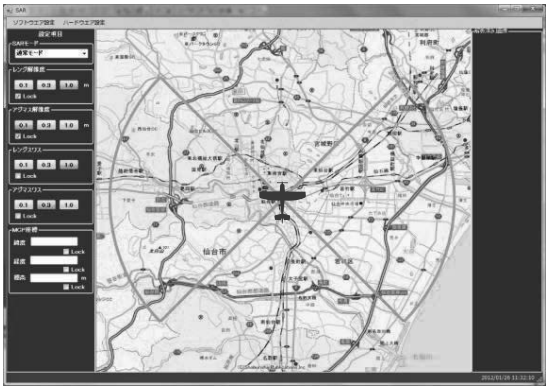


Fig.2 Graphical user interface.
Images can be gotten in fan-shaped area.

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 inFig.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 inFig.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]

[1] M. Inutake, et al., Exhibition of "Live SAR", Risk Control in Tokyo, Tokyo Big Site, Oct. 19-21 (2011).
[2] D. Zhang and A. Mase, "Experimental Study on Radar-Based Breast Cancer Detection Using UWB Antenna without Background Subtraction", Biomed. Eng.: Applications, Basis and Communications **23**, 5, 383-391
[3] M. Watanabe, C. Yonezawa, J. Iisaka, and M. Sato, "ALOS/PALSAR full polarimetric observations of the Iwate/Miyagi nairiku earthquake of 2008", Int. J. Remote Sensing **33**, 4, 1234-1245 (2012).

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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) Electomagnetic Bioinformation Engineering, (2) Advanced Acoustic Information Systems, (3) Visual Cognition and Systems, and (4) Ubiquitous Communications Systems.

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

(1) Electomagnetic 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.

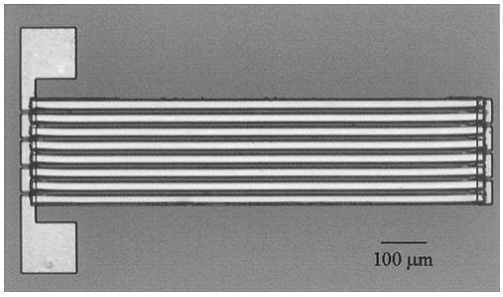

Fig.1 Sensitive magnetic field sensor

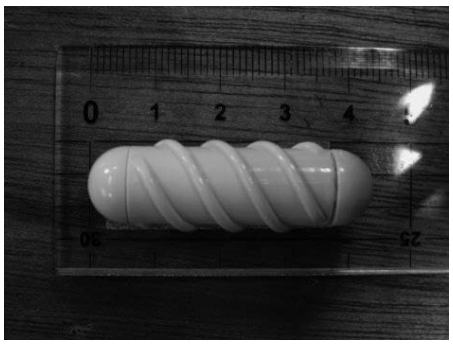

Fig. 2 Magnetic actuator for capsule-endoscope

[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]

[1] S. H. Kim, S. Hashi, and K. Ishiyama, "A basic study of a triangular magnet chain for locomotion control," J. App. Phys., Vol. 109, pp. 07E318-07E318-3, (2011).
[2] S. Hashi, S. Yabukami, H. Kanetaka, K. Ishiyama, and K. I. Arai, "Wireless Magnetic Position-Sensing System Using Optimized Pickup Coils for Higher Accuracy," IEEE Trans. Magn., Vol. 47, pp. 3542-3545, (2011).
[3] H. Nasuno, S. Hashi, and K. Ishiyama, "Stroboscopic Technique for Measuring Magnetic-Field Waveforms Utilizing Magneto-Optical Effect," IEEE Trans. Magn., Vol. 47, pp. 4011-4013, (2011).
[4] S. H. Kim, S. Hashi, and K. Ishiyama, "A Method for Acquiring the Torque of a Magnetic Pump," IEEE Transactions on Magnetics, Vol. 47, No. 10, pp. 3971-3974, (2011).
[5] S. H. Kim, S. Hashi, and K. Ishiyama, "Magnetic Robotics: A Biologically Inspired Walking Robot," Journal of Magnetic Society Japan, Vol. 35, pp. 149-156, (2011).

Advanced Acoustic Information Systems

Development of next generation communication systems

Advanced Acoustic Information Systems: Yôiti 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 supre-definition audio-visual display systems. Moreover, in 2011, we put a lot of efforts to investigate the spaciotemporal integration process of multisensory information processing.

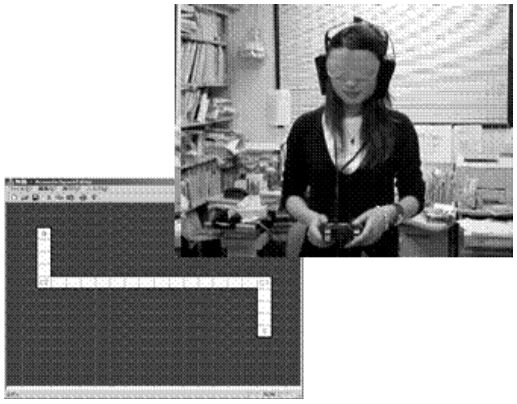

Fig. 1 Application for training spatial cognition based on high-definition virtual auditory display

[Staff]

Professor: Yôiti 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]

Yôiti Suzuki graduated from Tohoku University in 1976 and received his Ph. D. degree in electrical and communication engineering in 1981. His research interests include psychoacoustics and digital signal processing of acoustic signals. He served as a president of the Acoustical Society of Japan from '05 to '07. He is a fellow of the Acoustical Society of America.
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]

- Takuma Okamoto, et al., "Wide-band dereverberation method based on multichannel linear prediction using prewhitening filter," Applied Acoustics, 73(1), 50-55 (2012)
- Junfeng Li, et al., "Two-Stage Binaural Speech Enhancement with Wiener Filter (TS-BASE/WF) for High-Quality Speech Communication," Speech Communication, 53(5), 677-689 (2011)
- K. Asakawa, et al., "Audio-visual synchrony perception of simplified speech sounds heard as speech and non-speech," Acoustical Science and Technology, 32(3), 125-128 (2011)

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Visual Cognition and Systems Laboratory

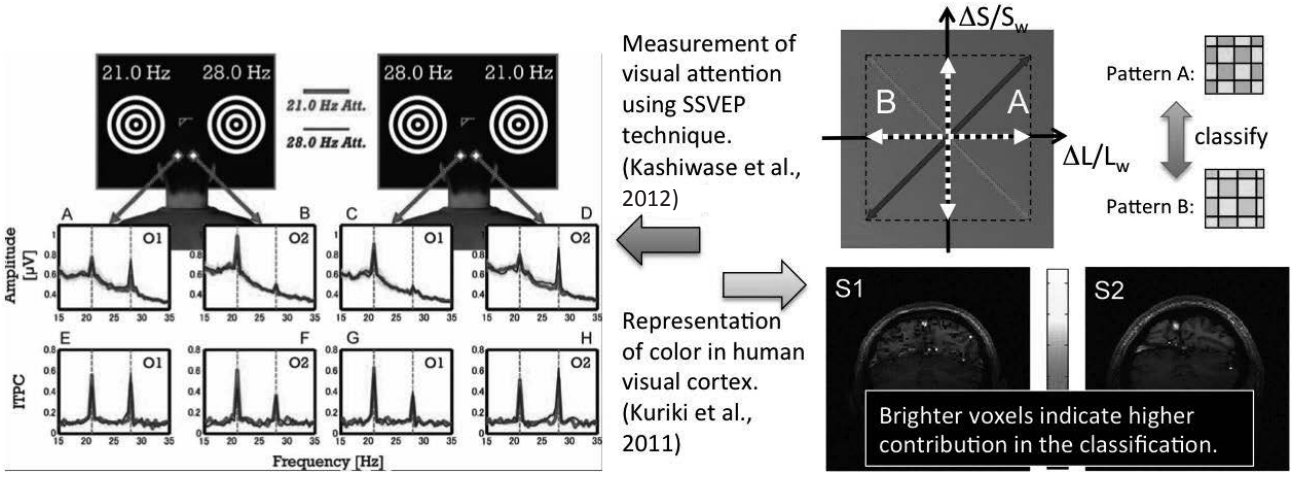
Understanding human visual system for the better communication with visual information

Visual Cognition and Systems: Satoshi Shioiri, Professor

Cognitive Brain Functions: Ichiro Kuriki, Associate Professor

[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]

[1] Control of subjective depth on 3-D displays by a quantified monocular depth cue. *Journal of the SID* 19/1, pp. 1-8, (2011). Takahashi S, Ishikawa T, Hyodo Y, Ohashi I, Shimpuku Y, Matsubara K, Matsumiya K, and Shioiri S

[2] Time courses of attentional modulation in neural amplification and synchronization measured with steady-state visual evoked potentials. *Journal of Cognitive Neuroscience* (2012). Kashiwase Y, Matsumiya K, Kuriki I, and Shioiri S.

[3] Decoding color responses in human visual cortex, *IEICE Trans. Funcamentals Vol. E94-A* (2) pp. 473-479(2011). Kuriki, I., Nakamura, S., Sun, P. Ueno, K., Matsumiya, K., Tanaka, K., Shioiri, S. and Cheng, K.

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.

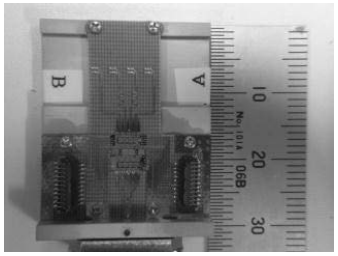


Fig. 1 Beam-forming Rx module

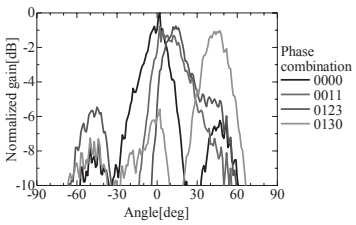


Fig. 2 Antenna directivity of Rx module

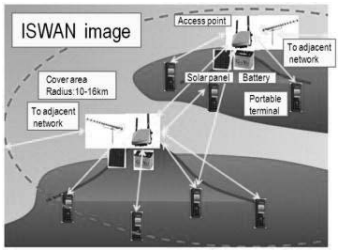


Fig.3 ISAWAN image

[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]

[1] K.Iigusa, H.Harada, S.Kato, J.Hirokawa, and M.Ando, "Periodically Loaded Straight Wires for Radio Wave Transmission Control", IEEE Trans. on Antennas and Propag., VOL. 59, NO. 1, JANUARY 2011.
[2] L.Materum, S.Kato, H.Sawada,“Channel Measurements for Short Range Beam Tracking/Switching Systems,”FrE1-1, ISAP2011, Oct. 25-28, 2011, Jeju, Korea.
[3] Y.Sato, K.Fujita, H.Sawada, H.Nakase, S.Kato, "A Millimeter-wave 8-element Double Slot Array Antenna for High Gain Beam-forming," GSMM2011, May 23-25, 2011, Espoo, Finland.

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Research Targets and Activities of Systems & Software Division

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

— Software Construction: Reliable and high-level software.
— Computing Information Theory: Fundamental theory of new software.
— Communication Network: Symbiotic computing.
— 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 framemwok. 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

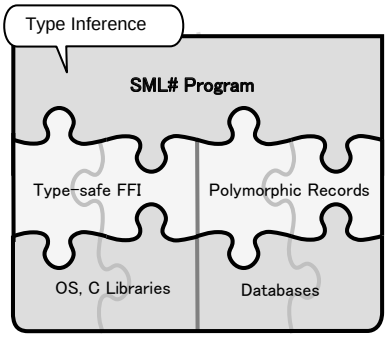
We focus on non-traditional contents other than movies, music and games, conducting comprehensive research on a variety of interactive content which creates new value through interactions with humans. This year we mainly conduct research projects on direct multi-touch interaction on a stereoscopic tabletop 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 Construcution

Foundations for Developing High-level and Reliable Programming Languages

Software Construction Atsushi Ohori, Professor

[Research Target and Activities]



SML#: a high-level and reliable language

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

The major results of 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]

[1] A. Morihata and K. Matsuzaki. Balanced trees inhabiting functional parallel programming. In Proc. the 16th ACM International Conference on Functional Programming, pp.117-128, 2011.
[2] K. Ueno, A. Ohori, and T. Otomo. An efficient non-moving garbage collector for functional languages. In Proc. the 16th ACM International Conference on Functional Programming, pp.196-208, 2011.
[3] A. Ohori and K. Ueno. Making Standard ML a practical database programming language. In Proc. the 16th ACM International Conference on Functional Programming, pp.307-319, 2011.

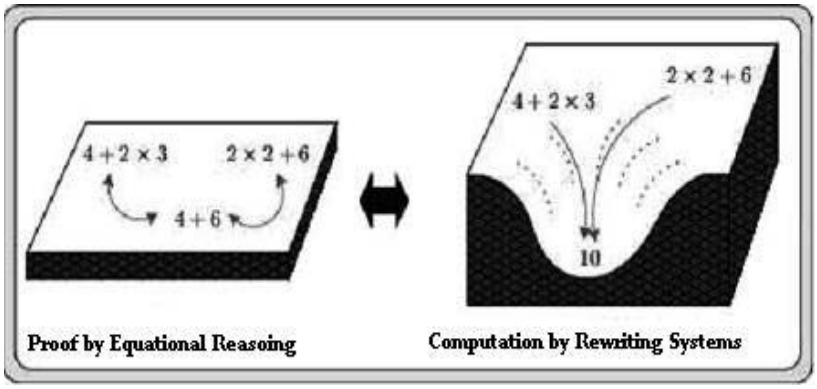
Computing Information Theory

Towards a New Software Paradigm Arising from Computation and Proof

Computing Information Theory **Yoshihito Toyama, Professor**
Computing logical system **Takahito Aoto, Associate Professor**

[Research Target and Activities]

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



[Staff]

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

[Profile]

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

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

[Papers]

[1] Takahito Aoto, Toshiyuki Yamada and Yuki Chiba, Natural inductive theorems for higher-order rewriting, In Proceedings of the 22nd International Conference on Rewriting Techniques and Applications (RTA 2011), LIPIcs, Vol.10, pp.107-121, 2011.

[2] Takahito Aoto and Yoshihito Toyama, Reduction-preserving completion for proving confluence of non-terminating term rewriting systems, In Proceedings of the 22nd International Conference on Rewriting Techniques and Applications (RTA 2011), LIPIcs, Vol.10, pp.91-106, 2011.

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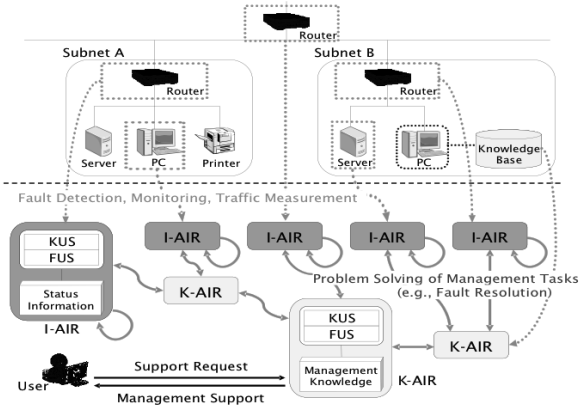
Communication Network

Support of Cooperation and Communication between Human and Systems

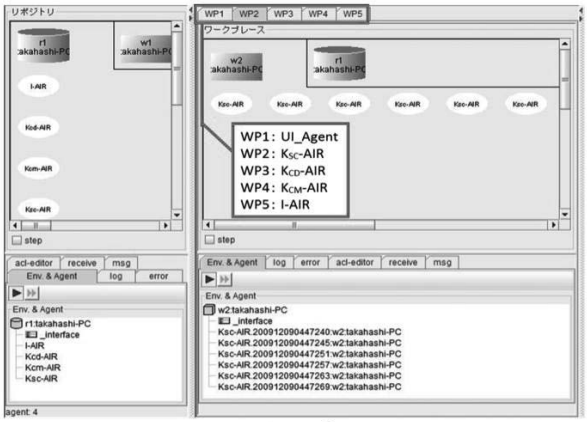
Intelligent Communication　Tetsuo Kinoshita, Professor

[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 framemwok. (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.



Configuration of AIR-NMS



Agent Monitor of AIR-NMS

[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]

[1] Akiko Takahashi, Tetsuo Kinoshita, "Configuration and control design model for an agent based Flexible Distributed System", International Journal of Web Intelligence and Agent Systems, Vol.9, No.2, pp.161–178, IOS Press, 2011.4.

[2] Takahiro Uchiya, Hideki Hara, Kenj Sugawara, Tetsuo Kinoshita, "Repository-Based Multiagent Framework for Developing Agent Systems", in Y. Wang (Ed.), Transdisciplinary Advancements in Cognitive Mechanisms and Human Information Processing, Ch.4, pp.60-79, IGI Global, ISBN 9781609605537, EISBN13: 9781609605544, 2011.5.

[3] Kazuto Sasai, Johan Sveholm, Gen Kitagata and Tetsuo Kinoshita, "A Practical Design and Implementation of Active Information Resource based Network Management System", Int. J. Energy, Information and Communication, Vol.2, N.4, pp.67-86, 2011.11.

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.

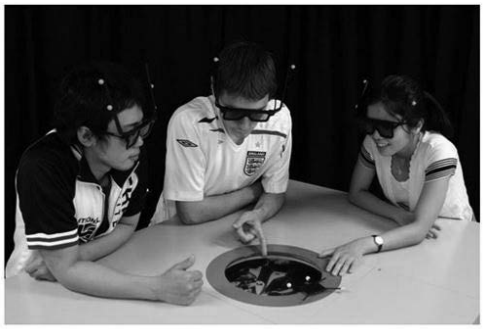


Fig. 1: Direct multi-touch interface on stereoscopic tabletop display

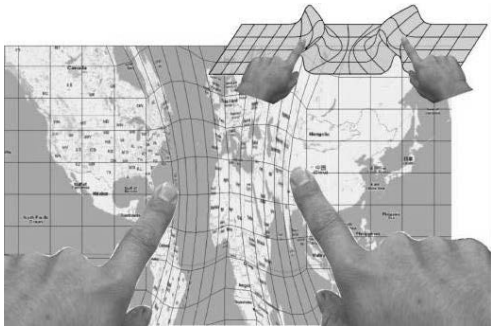


Fig. 2: Novel multi-touch interface with content distortion

[Staff]

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

[Profile]

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

[Papers]

[1] Kosuke Nakajima, Yuichi Itoh, Takayuki Tsukitani, Kazuyuki Fujita, Kazuki Takashima, Yoshifumi Kitamura, Fumio Kishino: FuSA2 touch display: furry and scaleble multi-touchable display, In Proc. Interactive Tabletops and Surfaces (ITS), pp. 35-44, Nov. 2011

[2] Kazuyuki Fujita, Yuichi Itoh, Hiroyuki Ohsaki, Naoaki Ono, Keiichiro Kagawa, Kazuki Takashima, Sho Tsugawa, Kosuke Nakajima, Hayashi Yusuke, Fumio Kishino: Ambient Suite: enhancing communication among multiple participants, In Proc. Advances in Computer Entertainment Technology (ACE), pp. 25:1-25:8, Nov. 2011.

[3] Sho Tsugawa, Hiroyuki Ohsaki, Yuichi Itoh, Naoaki Ono, Keiichiro Kagawa, Kazuki Takashima, Makoto Imase: Quasi-realtime social network construction with heterogeneous sensors in ambient environment, In Proc. Advances in Computer Entertainment Technology (ACE), pp. 75:1-75:2, Nov. 2011.

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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.

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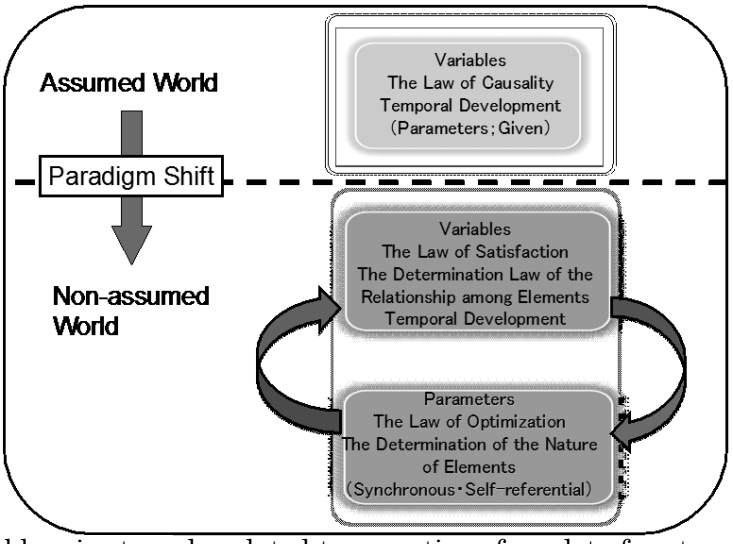

The unit commitment (UC) problem is strongly related to operations for a lot of systems, especially power systems. Many solutions have been extensively investigated. Conventional methods have been based on forecasted scenarios and have not been dynamic or autonomous. Distributed generation systems such 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]

[1] Jumpei Matsumoto, Yoshinari Makino, Haruki Miura, Masafumi Yano,(2011) "A computational model of the hippocampus that represents environmental structure and goal location, and guides movement", Biol.Cybern, vol.105,pp139-152

[2] Masafumi Yano,(2012) "Change Japan" , Monograph, EHESC Publishing,

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."

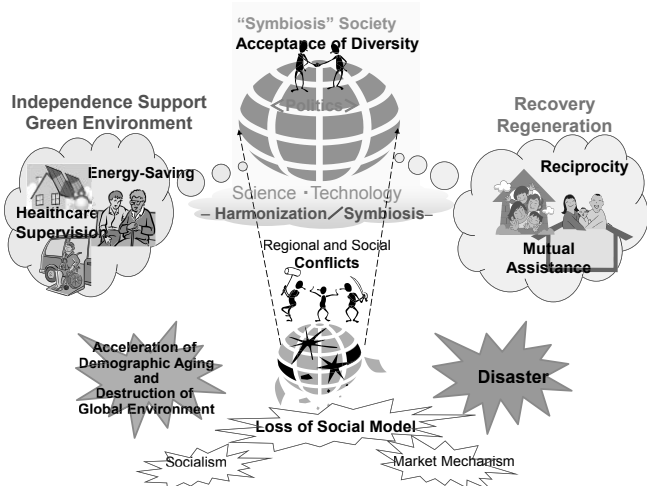

Fig.1: Model of Symbiotic Information Society towards Recovery and Regeneration

<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 CO_2 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 bone 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 Wining Paper Award in 1985, IPSJ Best Paper Award in 1996, IPSJ Contribution Award in 2007, IEICE Achievement Award in 2001, IEICE Best Paper Award, IEEE ICOIN-11 Best Paper Award in 1997, IEEE ICOIN-12 Best Paper Award in 1998, IEEE ICPADS Best Paper Award in 2000, IEEE 5-th WMSCI Best Paper Award in 2001, UIC-07 Outstanding Paper Award in 2007, Telecommunication Advancement Foundation Incorporation Award in 1991, Tohoku Bureau of Telecommunications Award in 2002, The Commendation for Science and Technology by the MEXT, in 2009, 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]

[1] Kazuo Hashimoto, Gen Kitagata, Hideyuki Takahashi, Atushi Takeda, Debasish Chakraborty, and Norio Shiratori, `` Socio-familiar Personalized Service and Its Application : Towards a New Network Software for Next Generation Ubiquitous Service," IEICE Transactions on Communications, Vol.J94-B, No.4, pp.492-502, Apr. 2011. **(Invited Paper)**

[2] Norio Shiratori, Kenji Ssugawara, Yusuke Manabe, Shigeru Fujita, Basabi Chakraborty ``Symbiotic Computing Based Approach Towards Reducing User's Barden Due to Information Explosion,'' Journal of Information Processing, Vol.20, No.1, pp.37-44, Jan. 2012. **(Invited Paper)**

[3] Noriaki Uchida, Kazuo Takahata, Yoshitaka Shibata, and Norio Shiratori, ``A Large Scale Robust Disaster Information System based on Never-Die Network,'' Proc. of the 26th IEEE International Conference on Advanced Information Networking and Applications (AINA2012), pp.89-96, March, 2012.

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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 (^{60}Co) 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.

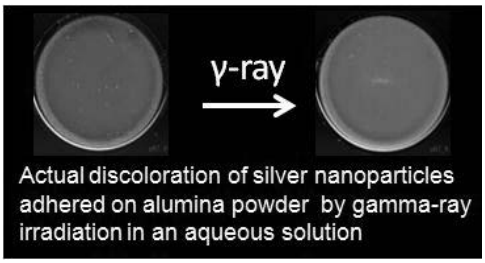
Environmental-Adaptive Information and Communication Engineering

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.



Actual discoloration of silver nanoparticles adhered on alumina powder by gamma-ray irradiation in an aqueous solution

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 (^{60}Co) 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]

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

[Papers]

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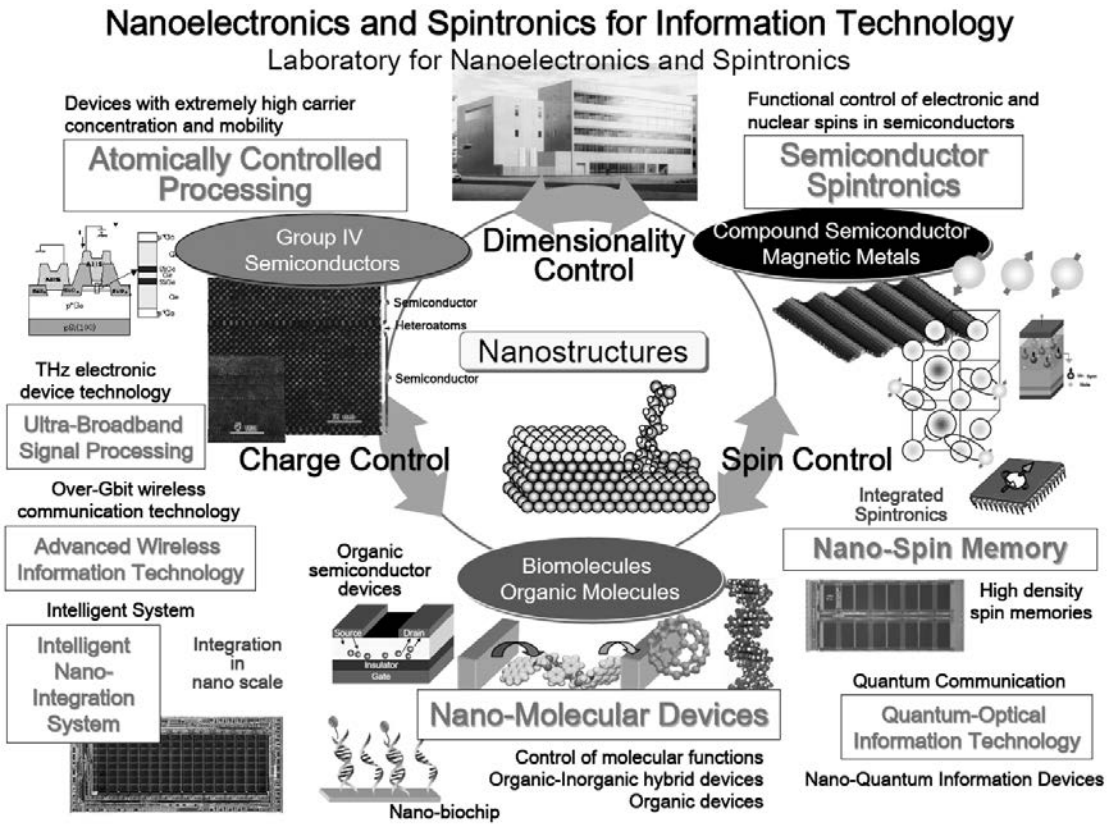
Laboratory for Nanoelectronics and Spintronics

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

The Laboratory for Nanoelectronics and Spintronics mainly consists of research groups which promote following sections: 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 ^{o}C, Si_3N_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 characterstics.

● 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_{eff}~1.8 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 ~1×10^7 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 SiO_2. 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

Atomically Controlled Processing Junichi Murota, Professor
Group IV Quantum Heterointegration Masao Sakuraba, Associate Professor

[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 $Si_{0.3}Ge_{0.7}$(100) at 400 °C, Si_3N_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 atoms 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.

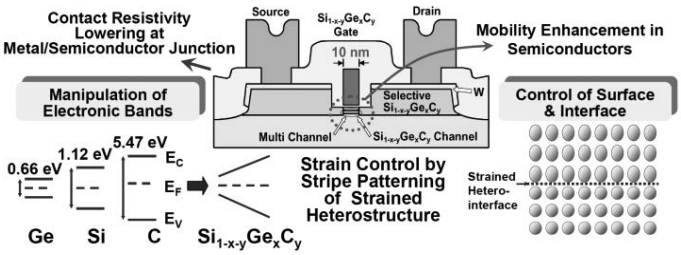


Fig. 1. 10 nm-scale quantum nanodevices with strain controlled nano-scale patterned heterostructure of group IV semiconductors.

[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]

[1] T. Kawashima, M. Sakuraba, B. Tillack and J. Murota, "Behavior of N Atoms after Thermal Nitridation of $Si_{1-x}Ge_x$ Surface", Thin Solid Films, Vol.520, pp.3392–3396 (2012).
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[3] J. Murota, M. Sakuraba and B. Tillack, "Atomically Controlled Processing in Silicon-Based CVD Epitaxial Growth", J. Nanosci. Nanotechnol., Vol.11, pp.8348-8353 (2011).

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Semiconductor Spintronics

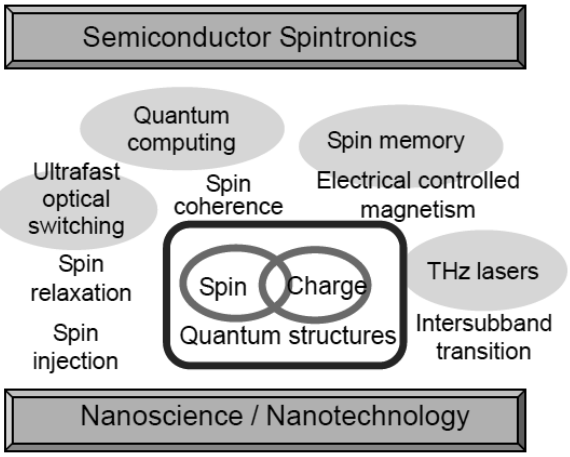
Nanoscience and Nanotechnology for Spintronics and THz Lasers

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]

[1] J. Ishihara, M. Ono, G. Sato, S. Matsuzaka, Y. Ohno, and H. Ohno, "Magnetic Field Dependence of Quadrupolar Splitting and Nuclear Spin Coherence Time in a Strained (110) GaAs Quantum Well," Japanese Journal of Applied Physics, Vol. 50, 04DM03 (3 pages), April 2011.
[2] S. Kanai, M. Endo, S. Ikeda, F. Matsukura, and H. Ohno, "Magnetic Anisotropy Modulation in Ta/ CoFeB/ MgO Structure by Electric Fields," Journal of Physics: Conference Series, Vol. 266, 012092 (5 pages), 2011.
[3] M. Ghali, K. Ohtani, Y. Ohno, and H. Ohno, "Generation and control of polarization-entangled photons from GaAs island quantum dots by an electric field," Nature Communications, Vol. 3, 661 (6 pages), February 2012.

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

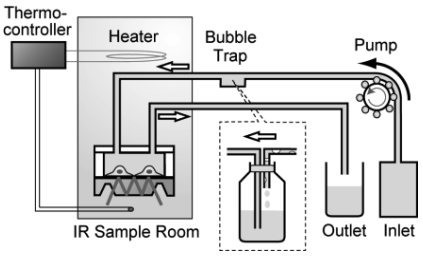
Porous Ti/Al composite counter electrodes were developed for dye-sensitized solar cells (DSCs). The composite counter electrodes reduced the sheet resistance to increase the fill factor.

2) Simulations of pharmacological actions in the basal ganglia circuit

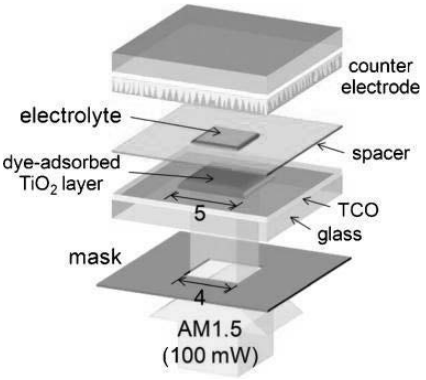
Computational simulations were carried out to investigate pharmacological effects in the basal ganglia (BG). They demonstrated that dopamine depletion in the BG and the frontal cortex causes delay of eye movements and induces oscillation of the neuronal activity in the BG.

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.



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



The structure of DSC using a porous Ti/Al composite counter electrode

[Staff]

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

[Profile]

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

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

[Papers]

[1] Mohammad Maksudur Rahman, Ryota Kojima, El Fassy Fihry Mehdi, Daisuke Tadaki, Teng Ma, Yasuo Kimura, Michio Niwano, "Effect of Porous Counter Electrode with Highly Conductive Layer on Dye-Sensitized Solar Cells", Jpn. J. Appl. Phys., Vol. 50, pp.082303-1-082303-5, 2011

[2] Keiichiro Nozawa, Azusa Oshima, Tomohiro Nasu, Atsushi Shoji, Ayumi Hirano-Iwata, Michio Niwano and Masao Sugawara, "In situ modification of lipid-loaded MCM-41 channels with bovine serum albumin at a planar lipid bilayer for biosensing", Sensors and Actuators B: Chemical, Vol.160, Issue 1,pp. 139-144 , 2011.

[3] Azusa Oshima, Ayumi Hirano-Iwata, Tomohiro Nasu, Yasuo Kimura, and Michio Niwano, "Mechanically Stable Lipid Bilayers in Teflon-Coated Silicon Chips for Single-Channel Recordings", Micro and Nanosystems, Vol.4, No.1, pp.2-7, 2012.

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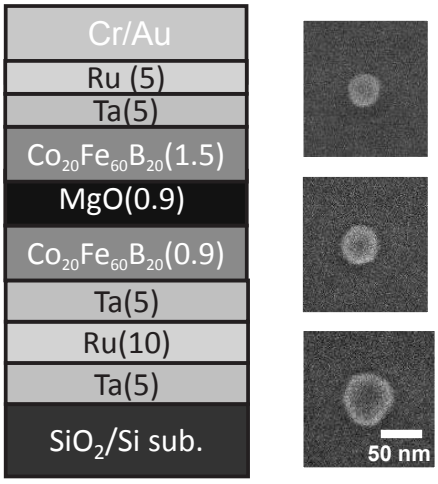
Nano-Spin Memory

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 nmϕ. 2) We have investigated the origin of reduced tunnel magnetroresistance (TMR) ratio of the p-MTJs with 40 nmϕ 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.



Schematic of perpendicular anisotropy CoFeB/MgO-based magnetic tunnel junction (MTJ) with different junction size.

[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]

[1] K. Miura, S. Ikeda, M. Yamanouchi, H. Yamamoto, K. Mizunuma, H. D. Gan, J. Hayakawa, R. Koizumi, F. Matsukura, and H. Ohno, "CoFeB/MgO based perpendicular magnetic tunnel junctions with stepped structure for symmetrizing different retention times of “0” and “1” information," Dig. Tech. Pap. - Symp. VLSI Technol. 2011, 214.
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[3] H. D. Gan, H. Sato, M. Yamanouchi, S. Ikeda, K. Miura, R. Koizumi, F. Matsukura, and H. Ohno, "Origin of the collapse of tunnel magnetoresistance at high annealing temperature in CoFeB/MgO perpendicular magnetic tunnel junctions," Appl. Phys. Lett, Vol.99, 252507, December 2011.

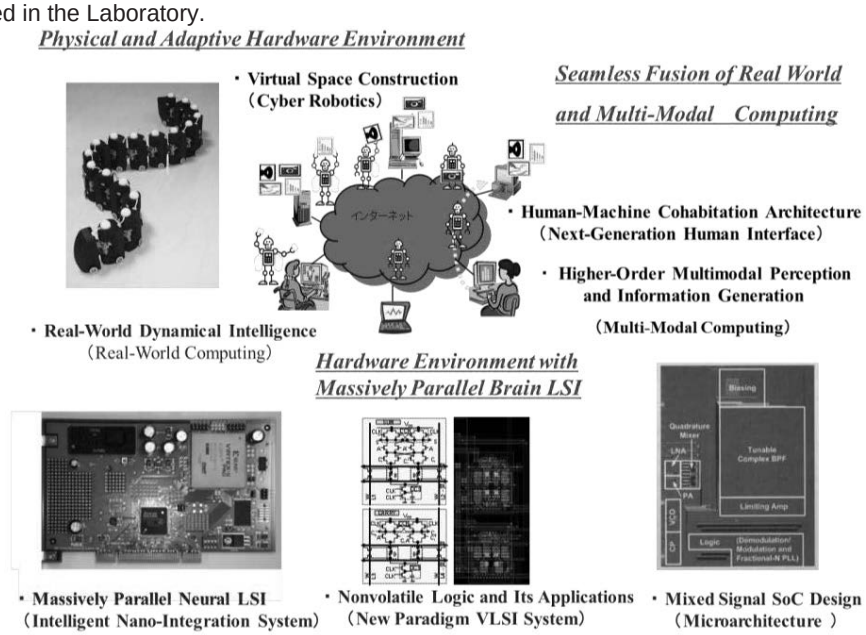
Laboratory for Brainware Systems

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 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.

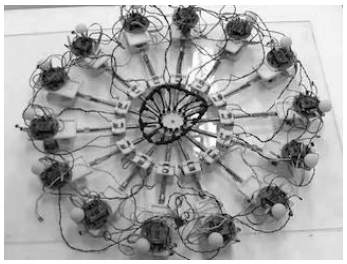


Fig.1: Soft-bodied amoeboid robot driven by a fully decentralized control scheme extracted from true slime mold

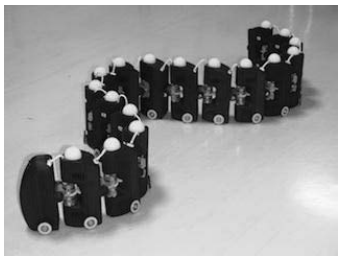


Fig.2: Decentralized control of a snake-like robot that exhibits highly adaptive and resilient properties

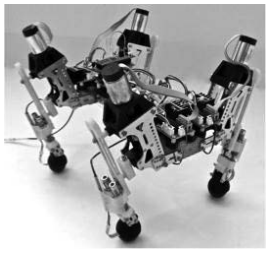


Fig.3: Quadruped robot driven by a fully decentralized neural network-based control.

[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]

[1] W. Watanabe, T. Kano, S. Suzuki, and A. Ishiguro, "A decentralized control scheme for orchestrating versatile arm movements in Ophiuroid omnidirectional locomotion", Journal of Royal Society of Interface, Vol.9, No.6, 2011 (DOI: 10.1098/rsif.2011.0317)

[2] T. Sato, T. Kano, and A. Ishiguro, "A decentralized control scheme for an effective coordination of phasic and tonic control in a snake-like robot", Bioinspiration & Biomimetics, Vol.7, No.1, 2012 (DOI: 10.1088/1748-3182/7/1/016005)

[3] T. Umedachi, R. Idei, T. Nakagaki, R. Kobayashi, and A. Ishiguro, "Fluid-filled Soft-bodied Amoeboid Robot Inspired by Plasmodium of True Slime Mold", Advanced Robotics, Vol.26, pp.693-707, 2012

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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.

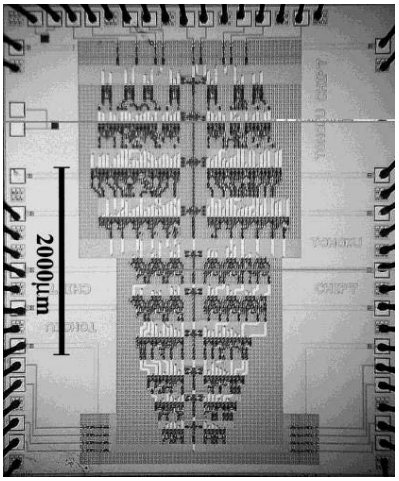


Figure A 4-bit parallel multiplier using SFQ logic

[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]

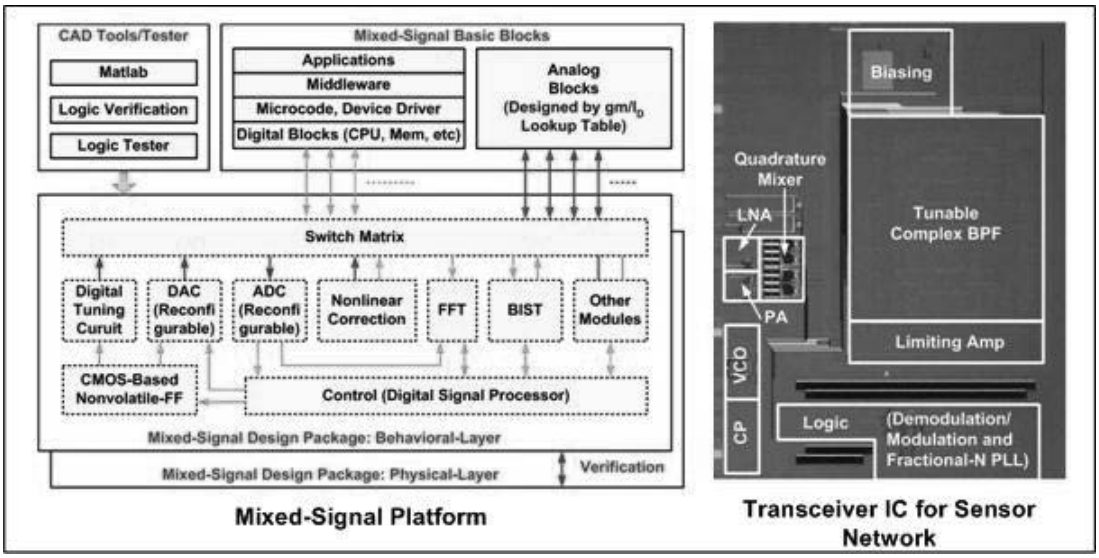
[1] T. Sota, Y. Hayakawa, S. Sato, and K. Nakajima, “An application of higher order connection to inverse function delayed network,” Nonlinear Theory and Its Appl., IEICE, vol. 2, no. 2, pp. 180-197, 2011.
[2] S. Sato, A. Ono, M. Kinjo and K. Nakajima, “Performance evaluation of adiabatic quantum computation using neuron-like interconnections,” Nonlinear Theory and Its Appl., IEICE, vol. 2, no. 4, pp. 198-204, 2011.
[3] T. Onomi, Y. Maenami, and K .Nakajima, “Superconducting neural network for solving a combinatorial optimization problem,” IEEE Trans. Applied Superconductivity, vol.21, no.3, pp.701-704, 2011.

Microarchitecture Laboratory

Mixed-Signal Platform Design

Microarchitecture Shoichi Masui, Professor

[Research Target and Activities]



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]

[1] D. Su, M. Loinaz, S. Masui, and B. Wooley, "Experimental Results aand Modeling Techniques for Substrate Noise in Mixed Signal Integrated Circuits," Journal of Solid-State Circuits, vol. 28, no. 4, pp. 420-430, 1993.
[2] S. Masui, et al., "Ferroelectric Memory Based Secure Dynamically Programmable Gate Array", IEEE J. of Solid-State Circuits, vol. 38, no. 5, pp. 715-725, 2003.
[3] T. Konishi, K. Inazu, J. G. Lee, M. Natsui, S. Masui, B. Murmann, "Design Optimization of High-Speed and Low-Power Operational Transconductance Amplifier Using g_m/I_D Lookup Table Methodology," IEICE Trans. on Electronics, vol.E94-C, no.3, pp. 334-345, 2011.

New Paradigm VLSI System Research Group

Realization of a New-Paradigm VLSI-Computing World

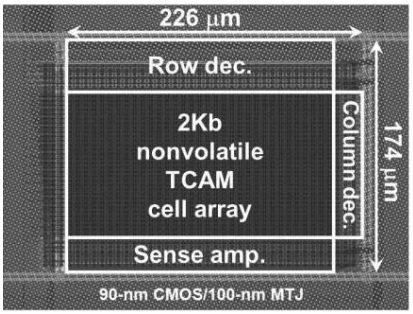


Fig.1: MTJ/MOS-hybrid nonvolatile TCAM chip. Standby-power-free TCAM has been realized with minimum transistor counts by merging logic and storage functions

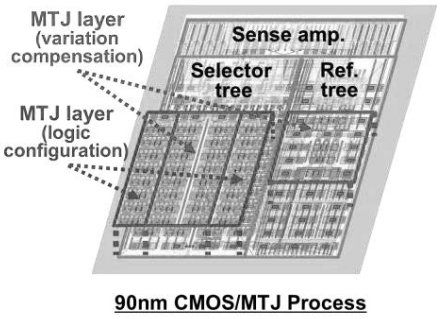


Fig.2: Compact nonvolatile LUT circuit using series/parallel-connected MTJ devices.

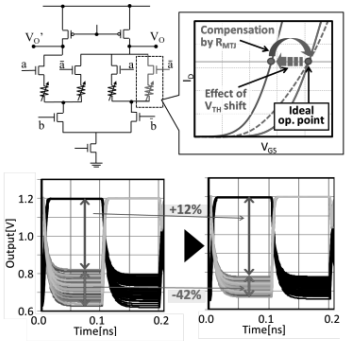


Fig.3: Differential current-mode logic circuit with MTJ-based variation compensation capability.

[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 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 Vth-tuning function.

[Staff]

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

[Profile]

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

[Papers]

[1] S. Matsunaga, A. Katsumata, M. Natsui, S. Fukami, T. Endoh, H. Ohno, and T. Hanyu, "Fully Parallel 6T-2MTJ Nonvolatile TCAM with Single-Transistor-Based Self Match-Line Discharge Control," 2011 Symposium on VLSI Circuits, Digest of Technical Papers, 28-2, pp.298-299, June 2011.
[2] N. Onizawa, V. C. Gaudet, and T. Hanyu, "Low-Energy Asynchronous Interleaver for Clockless Fully Parallel LDPC Decoding," IEEE Trans. on Circuits and Systems Part I, Vol.58, No.8, pp.1933-1943, August 2011.
[3] D. Suzuki, M. Natsui, T. Endoh, H. Ohno, and T. Hanyu, "Six-input lookup table circuit with 62% fewer transistors using nonvolatile logic-in-memory architecture with series/parallel-connected magnetic tunnel junctions", Journal of Applied Physics, Vol.111, Issue 7, pp.07E318(1)-07E318(3), Feb. 24, 2012.

IT-21 center

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

[Research Target and Activities]

The purpose of the IT-21 center is development of practical technologies for IT based on the advanced technologies of RIEC with the partnership among Industry, Government and University. The term of development is limited less than 5 years. The projects are planed on matching with both basic technologies in the University and application in the Industry. Combination of the technologies of the University and Industry makes practical technologies with availability for the commercial products. The center actively accelerates to obtain the intellectual properties generated from the development of practical technology to the Industry. 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 IP 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 5 Tbits/inch^2 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/inch^2, (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]

[1] S. Yoshida et al., "A low cross polarization 5 GHz-band 3-stacked meander-line antenna integrated with a meander-line shape balun," 5th European Conference on Antennas and Propagation (EuCAP2011), Italy, April 2011.
[2] K. Komatsu et al., "ASIC implementation of frequency domain equalizer for single carrier transmission," XXX URSI General Assembly and Scientific Symposium of International Union of Radio Science (URSI GASS 2011), Istanbul, Turkey, August 2011.
[3] T. T. Ta et al., "A high efficiency Si-CMOS power amplifier for 60 GHz band broadband wireless communication employing optimized transistor size," European Microwave Conference (EuMC), Manchester, UK, Oct. 2011.

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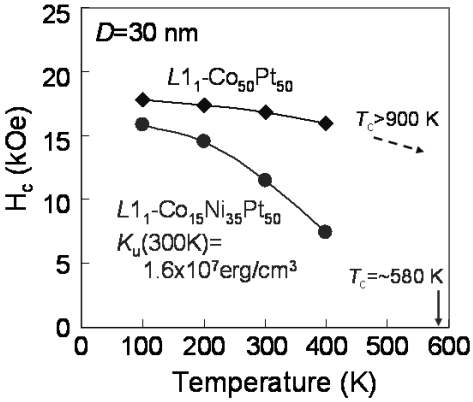
IT-21 center, Technology Development Division, Storage Technology Group

Development of low power consumption mass storage HDD systems

Kazuhisa 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 Tbits/inch^2 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 Tbits/inch^2). We simulated that the recording density of 5 Tbits/in^2 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 $L1_1$-$Co_{15}Ni_{35}Pt_{50}$ dot arrays, which had a large magnetic anisotropy K_u of 1.6x10^7 erg/cm^3 (300 K) and a low curie temperature T_c 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.



Temperature dependence of H_r for $L1_1$-$Co_{15}Ni_{35}Pt_{50}$ dot arrays with dot diameter of 30 nm.

[Staff]

Professor: Kazuhisa 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., Hirotoshi Akaike, 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]

Kazuhisa 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]

[1] H. Saga, K. Shirahata, K. Mitsuzuka, T. Shimatsu, H. Aoi, and H. Muraoka, "Impact of Multidomain Dots on Write Margin in Bit Patterned Media Recording," *IEEE Trans. Magn.*, vol.47, 2528-2531 (2011).
[2] T. Shimatsu, H. Kataoka, K. Mitsuzuka, H. Aoi, N. Kikuchi, and O. Kitakami, "Dry-etching damage to magnetic anisotropy of Co-Pt dot arrays characterized using anomalous Hall effect," *Journal of Applied Physics*, vol. 111, 07B908(1-3) (2012).

Contact to Professor Kazuhisa Fujimoto : fujimoto@riec.tohoku.ac.jp

Management Office for Health and Safety

Realizing and Maintaining a Safe and Comfortable Environment to Support Research

[Research Target and Activities]

Safety and health seminar

First aid training course

1. Outline of the Management Office for Health and Safety

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

2. Activities by the Management Office for Health and Safety

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

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

[Staff]

Manager: Michio Niwano, Professor

Deputy Manager: Yoichi Uehara, Professor

Nobuyuki Sato, Assistant Professor

Ayako Chiba, Clerk

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:

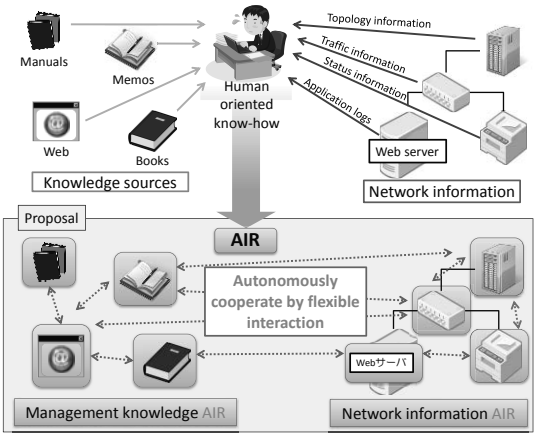


Fig.1 Knowledge based Network Management System.

(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.

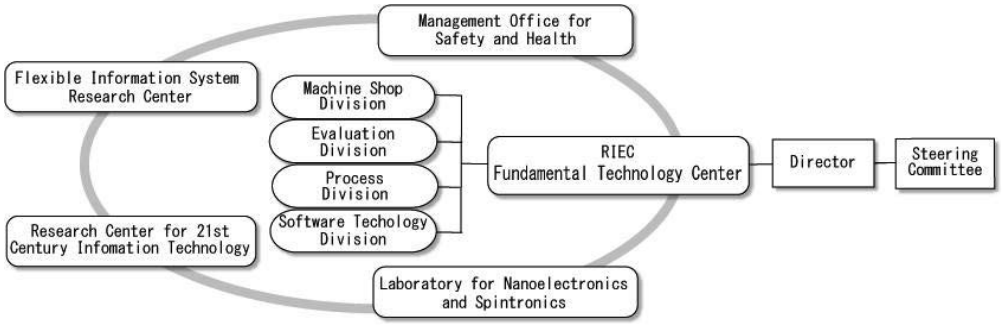
[Papers]

1. Gen Kitagata, Kazuto Sasai, Johan Sveholm, Norio Shiratori, and Tetsuo Kinoshita," Agent-based Access Rights Delegation utilizing Social Relationships ," International Journal of Energy, Information and Communications, Vol.2, No.4, pp.87-100, 2011.11.
2. Kazuto Sasai, Johan Sveholm, Gen Kitagata, and Tetsuo Kinoshita," A Practical Design and Implementation of Active Information Resource based Network Management System ," International Journal of Energy, Information and Communications, Vol.2, No.4, pp.67-86, 2011.11.

Contact to Associate Professor Gen Kitagata : minatsu@fir.riec.tohoku.ac.jp

Fundamental Technology Center

Supporting research with high-level specialized knowledge and technology



Overview of Fundamental Technology Center

[Research Target and Activities]

The Fundamental Technology Center provides a wide range of technical 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

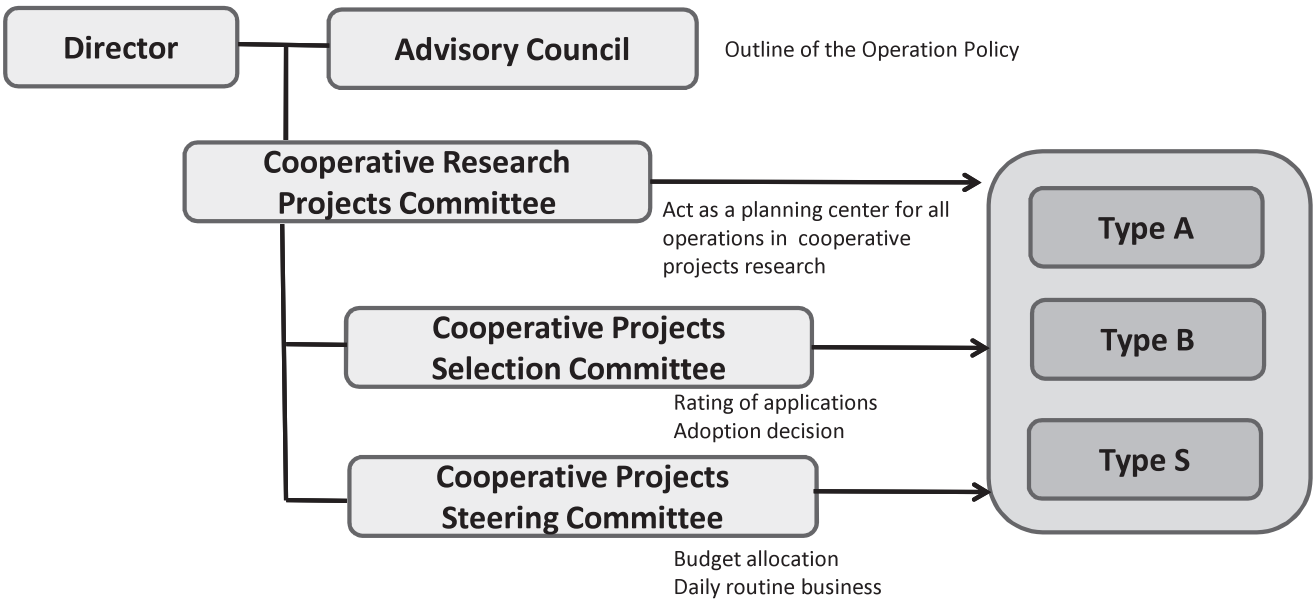
4. Nation-wide Cooperative Research Projects

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.



Nation-wide Cooperative Research Projects list 2011

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H21／A04 Evaluation of Piezoelectric Langasite Family Compounds by the Ultrasonic Microspectroscopy and Piezoelectric Resonant-Antiresonant Frequencies Measurement Methods and their Applications to High-Temperature Sensors	**Jun-ichi Kushibiki** Graduate School of Engineering, Tohoku University	**Yasuo Cho**
H21／A05 Study on spintronic application of the oxide thin films with Magneto-Electric effect	**Seiji Sahashi** School of Engineering, Tohoku University	**Kazushi Ishiyama**
H21／A06 STT microwave oscillation of self-organized multi-nano-pillar structure and its application	**Masaaki Doi** Graduate School of Engineering, Tohoku University	**Kazushi Ishiyama**
H21／A08 High performance THz signal sources employing serially-connected resonant tunneling diodes	**Koichi Maezawa** Graduate School of Science and Engineering. University of Toyama	**Taiichi Otsuji**
H21／A10 A Study on Higher Realistic Communication in Three Dimensional Sound Space	**Kazuhiro Kondo** Graduate School of Science and Engineering. Yamagata University	**Yukio Iwaya**
H21／A11 The cooperative system to built a model of visual cognition	**Satoshi Shioiri** Research Institute of Electrical Communication Tohoku University	**Satoshi Shioiri**
H21／A13 Creation of Platform for Sustainable Information Society by Sensor-Cloud Systems	**Osamu Takahashi** Future University-Hakodate	**Tetsuo Kinoshita**
H22／A01 Study on terahertz optoelectronic devices using graphene	**Ryzhii Victor** University of Aizu	**Taiichi Otsuji**

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H22／A02 Formation and Valency Control of Ge-based Quantum Dots and Their Application to Nanoscale Functional Memories	**Seiichi Miyazaki** Graduate School of Engineering. Nagoya University	**Jun-ichi Murota**
H22／A03 Computational Materials Design and Device Applications of Magneto-electric and Magneto-elastic Effects	**Tatsuki Oda** College of Science and Engineering. Kanazawa University	**Masafumi Shirai**
H22／A04 Study on High-Efficiency Switching-Mode Power Amplifier with InGaAs HEMTs	**Yohtaro Umeda** Tokyo University of Science Faculty of Science and Technology Electrical Engineering	**Tetsuya Suemitsu**
H22／A05 Broadband light generation and detection using electron tunneling	**Yoichi Uehara** Research Institute of Electrical Communication Tohoku University	**Yoichi Uehara**
H22／A06 Research of spintronics devices with negative spin-polarization materials	**Masakiyo Tsunoda** Graduate School of Engineering, Tohoku University	**Masafumi Shirai**
H22／A07 Chemical synthesis of pure Fe nanoparticle assembly with high saturation magnetization and its soft magnetic properties	**Migaku Takahashi** Graduate School of Engineering, Tohoku University	**Kazushi Ishiyama**
H22／A08 Research on personal acoustic telepresence system	**Tatsuya Hirahara** Toyama Prefectual University	**Yôiti Suzuki**
H22／A09 Multimodal speech communication system based on human perceptual property	**Akihiro Tanaka** Waseda Institute for Advanced Study	**Shuichi Sakamoto**
H22／A10 The Influence of a Natural Sound on Stress Responses	**Shin Fukudo** Tohoku University School of Medical	**Yôiti Suzuki**

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H22／A11 Development of universal training system using acoustic virtual reality technique	**Makoto Oh-uchi** Faculty of General Management. Tohoku Fukushi University	**Yukio Iwaya**
H22／A12 Directivity control on frequency domain binaural model	**Yoshifumi Chisaki** Kumamoto University	**Yôiti Suzuki**
H22／A13 Study of Brainware Systems	**Toshiyuki Kanoh** NEC Corporation	**Junji Tada**
H22／A14 Fundamental Study to Obtain Understanding on Working Network to Fully Make Use of the Knowledge	**Ryuji Igarashi** Administration Department Faculty of Engineering and Resource Science, Akita University	**Gen Kitagata**
H22／A16 Advanced study on a real-world oriented computing application based on the symbiotic computing	**Shigeru Fujita** Chiba Institute of Technology	**Tetsuo Kinoshita**
H23／A01 Basis Establishment of Plasma Nanobiotronics	**Rikizou Hatakeyama** Graduate School of Engineering, Tohoku University	**Michio Niwano**
H23／A02 Optoelectronic devices using carbon-based nanomaterials	**Takashi Uchino** Tohoku Institute of Technology	**Jun-ichi Murota**
H23／A03 Development of the fabrication technique for atomically-controlled Si- and Ge-MIS structures and the evaluation technique of their interfaces	**Hiroshi Okamoto** Hirosaki University	**Jun-ichi Murota**
H23／A04 Highly-Strained and Atomically-Controlled Heterostructure Formation of Group-IV Semiconductors and Nanodevice Application	**Jun-ichi Murota** Research Institute of Electrical Communication Tohoku University	**Jun-ichi Murota**

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H23／A05 Study on the influence of hetero-interface on the electrical characteristics of ultrathin hetero-epitaxial layers	Toshiaki Tsuchiya Shimane University Interdisciplinary Faculty of Science and Engineering	Jun-ichi Murota
H23／A06 Heterogeneous Network Roaming Technology for Dependable Air	Noriharu Suematsu Research Institute of Electrical Communication Tohoku University	Noriharu Suematsu
H23／A07 Spatial Perception and Multisensory Integration	Souta Hidaka Rikkyo University College of Contemporary Psychology	Yukio Iwaya
H23／A08 Signal transduction of the artificial neuronal network	Haruyuki Kamiya Hokkaido University Graduate School of Medicine School of Medicine	Michio Niwano
H23／A09 A research on flexible,printable organic heterojunction photovoltaic devices	Fumihiko Hirose Faculty of Egineering. Yamagata University	Michio Niwano
H23／A10 Development of magnetic devices using thin film element with inchlined stripe magnetic domain and its applications	Hiroaki Kikuchi Iwate University	Kazushi Ishiyama
H23／A11 Research on Infrastructure System for Cyber-Physical Integrated Society	Hiroshi Shigeno Keio Univercity Science and Technology	Gen Kitagata
H23／A12 Two-dimensional sound localization based on a monaural input signal	Masashi Itoh Tohoku Institute of Technology	Yôiti Suzuki
H21／B01 Fundamental characteristics and applications of innovative functional field generated by various plasma flow	Akira Ando Graduate School of Engineering Tohoku University	Maki Suemitsu

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H21／B02 Elucidation and Control of Graphene Growth for its applications in the next-generation devices	Maki Suemitsu Research Institute of Electrical Communication Tohoku University	Maki Suemitsu
H21／B03 Small Power Wireless Communications Systems	Shuzo Kato Research Institute of Electrical Communication Tohoku University	Shuzo Kato
H21／B04 Complex Valued Neural Network for Real Applications	Akira Hirose School of Engineering. The University of Tokyo	Shigeo Sato
H21／B05 Study on human performance with a view to designing human-friendly information systems	Hirofumi Yanai College of Engineering. Ibaraki University	Koji Nakajima
H21／B06 Toward an interdisciplinary approach of vision sciences	Ken-ichiro Tsutsui Graduate School of Life Science Tohoku University	Satoshi Shioiri
H21／B07 Novel Bioelectronic Devices Based on Combination of Nano and Bio-technology	Toshio Ogino Yokohama National University, Graduate School of Engineering	Michio Niwano
H21／B08 Understanding adaptive locomotion mechanism of biological system and its application to engineering	Ko Hosoda Graduate School of Engineering Osaka University	Akio Ishiguro
H21／B09 Evolution of high performance computing by non-volatile bits-operation technologies	Hiroshi Matsuoka Japan Atomic Energy Agency, Center for Computational Science & E-systems	Takahiro Hanyu
H21／B10 Research on Next-Generation Models of Digital Content Distribution	Isao Echizen National Institute of Informatics	Yôiti Suzuki
H21／B11 New Paradigm VLSI System and Its System Integration Technology	Takahiro Hanyu Research Institute of Electrical Communication Tohoku University	Takahiro Hanyu

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H22／B02 Application and Basic Study of Fine Particle Plasmas	**Tetsu Mieno** National University Corporation SHIZUOKA University	**Michio Niwano**
H22／B04 Photonics for novel interface of bioinformation	**Kazuhiro Sakamoto** Research Institute of Electrical Communication Tohoku University	**Kazuhiro Sakamoto**
H22／B05 New Principle Nano Devices Based on Nano-Scale Control of Fluctuation and Electron Correlations	**Shintaro Nomura** Graduate School of Pure and Applied Sciences University of Tsukuba	**Hideo Ohno**
H22／B06 Research of large-format quantum detector arrays with High-Q microwave superconducting resonators	**Toshiyuki Miyazaki** RIKEN	**Shigeo Sato**
H22／B07 Challenge and Perspective for Millimeter Wave Applications	**Yohei Ishikawa** Research Institute for Sustainable Humanosphere, Kyoto University	**Noriharu Suematsu**
H22／B08 Investigation of Bio-inspired Information Theory and its Technological Application	**Daisuke Uragami** Tokyo University of Technology	**Kazuto Sasai**
H22／B09 Study on visual information of material surface properties	**Katsunori Okajima** Yokohama National University	**Ichiro Kuriki**
H22／B10 Program Verification with Mathematical Logic	**Masahiko Sato** Kyoto University	**Yoshihito Toyama**
H22／B11 Development and Application of Synthetic Aperture Radar System for Civilian Use	**Atsushi Mase** Art, Science and technology Center for Cooperative Research, Kyushu University	**Hiroshi Yasaka**
H23／B01 Research for MEMS / high-frequency devices with nano-structured magnetic materials for advanced communications equipments	**Makoto Sonehara** Dept. of Electrical and Electronic Engineering, Faculty of Engineering, Shinshu University	**Kazushi Ishiyama**

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H23／B02 Research on the new concept large scale memory and its system with integration of nano materials on silicon technology	**Heiji Watanabe** Graduate School of Engineering, Osaka University	**Tetsuo Endo**
H23／B03 Research on nano semiconductor materials and nano structured devices required for future electronic systems	**Kikuo Yamabe** Graduate School of Pure and Applied Sciences Tsukuba University	**Tetsuo Endo**
H23／B04 New Technologies for Reducing Iron Loss of Electrical Steels	**Kazushi Ishiyama** Research Institute of Electrical Communication Tohoku University	**Kazushi Ishiyama**
H23／B05 Study of functional piezoelectric materials and applications to advanced communication devices	**Jun-ichi Kushibiki** Graduate School of Engineering Tohoku University	**Yasuo Cho**
H23／B06 Ultrafast Coherent Lightwave Control Technologies for Ultimate Communication and Measurement Systems	**Hidemi Tsuchida** National Institute of Advanced Industrial Science and Technology	**Masataka Nakazawa**
H23／B07 Research on Next-generation Peta-byte Information Storage	**Hiroaki Muraoka** Research Institute of Electrical Communication Tohoku University	**Hiroaki Muraoka**
H23／B08 Passive/Active Circuit Technologies and Their Applications for Next Generation RFIC	**Toshio Ishizaki** Faculty of Science And Technology. Ryokoku University	**Noriharu Suematsu**
H23／B09 Multisensory integration involving self-body motion	**Kenzo Sakurai** Faculty of liberal arts. Tohoku Gakuin University	**Yôiti Suzuki**
H23／B10 Next Generation Human Interface for Interactive Contents	**Yoshifumi Kitamura** Research Institute of Electrical Communication Tohoku University	**Yoshifumi Kitamura**

Project Number Research Project Theme	Project Leader	Facilitator in RIEC
H23／B11 Foundation of Dependable Cloud System with a Highly Reliable Programming Language System	Kazuhiko Kato Graduate School of Systems and Information Engineering Tsukuba University	Atsushi Ohhori
H21／S01 Information processing and communication system based on an innovative new concept associated with human functions	Masayuki Numao The Institute of Scientific and Industrial Research (ISIR) Osaka University	Masafumi Shirai
H23／S01 Development of essential technologies directed to systematization of superhivision	Hidenori Mimura Shizuoka University Research Institute of Electronics	Yôiti Suzuki
H23／S02 Spintronics International Alliance	Kohei Itoh Keio University Science and Technology	Hideo Ohno
H23／S03 Collaborative Research on Nano-electronics	Tetsuya Osaka Waseda Univ. Institute for Nanoscience & Nanotechnology	Michio Niwano

5. Symposium Organized by the Institute

This Symposium is planned to exchange relevant information on current important topics concerning Electrical Eng., Electrical Communications, Electronic Eng., and Information Eng. Many related researchers inside and outside Tohoku University participate the Symposium and stimulate discussion.

Symposium In Past

	Title	Date
1	Quantum Electronics of Liglht Waves and Micro Waves	Feb. 6- 8, 1964
	Magnetic Recording	Feb.14-15, 1964
2	Ultra-High Frequency Acoustelectronics	Feb.11-12, 1965
3	Artificial lntelligence	Mar. 8- 9, 1966
4	Thin Film Electronics	Jan.26-27, 1967
5	Crystal Growth	Dec. 19-20, 1967
6	1968 Sendai Symposium on Acoustelectronics	Aug.19-20, 1968
7	Current Status and Future Trends of Superconductivity	Jan.22-24, 1970
8	Speech Information Processing	Feb.24-26, 1971
9	Surface Acoustic Wave Technology	May 25-26, 1972
10	Liquid Crystals · Their Molecular Orientations and Application to Display Devices	Dec.13-14, 1974
11	Computer Network	Mar.17-18, 1975
12	The Memorial Symposium on the 40th Anniversarv of the Foundation of RIEC	Sep.25-26, 1975
13	Application of Amorphous Ferromagnetic Materials	Mar.10-11, 1977
14	Stoichiometry of Compound Crystals	Nov.24-25, 1977
15	Submillimeter Waves	Nov.16-17, 1978
16	Solid State Chemical Sensors	Feb. 1- 2, 1980
17	Graph Theory and Algorithms	Oct.24-25, 1980
18	Perpendicular Magnetic Recording	Mar.11-12, 1982
19	Approach to Optical Computer	Mar.10-11, 1983
20	Plasma Non-Linear Phenomena - Basic Problems for Fusion Plasmas	Mar. 8- 9, 1984
21	New Computer Architecture	Jul.25-26, 1985
22	Guided Wave Technology and Its Application at Mid-Infrared	Mar.13-14,1986
23	Physics and Applications of Tunnelling Phenomena	Mar.12-14, 1987
24	Biomagnetics and Bioelectronics	Feb.26-27, 1988
25	Ultrasonic Electronics - New Applications of Piezoelectricity	Feb. 2- 3, 1989
26	Boundaries between Light and Electromagnetic Wave	Feb. 1-2, 1990

27	Issues and Realization of Pattern Recognition and Understanding	Feb.28-Mar.1,1991
28	Discrete Algorithms	Oct.17-18, 1991
29	Perspective for New Computing Paradigm	Feb. 4- 5, 1993
	Current Status and Future Prospects of System Control	Mar. 3- 4, 1993
30	Future Prospects of Electron Beam Devices	Nov. 1- 2, 1993
31	Discharge and EMC	Dec.20-21, 1994
32	Statistical Physics and Information Science	Mar.22-23,1995
33	Photo-and Plasma-Excited Processes on Surfaces	Nov.30-Dec.1,1995
34	Nano Spinics and Power Electronics	Feb.15-16, 1996
35	Potential Formation and Related Nonlinear Phenomena in Plasmas	Sep.17-19, 1996
36	New Trend in Ultrasonic Measurements	Feb. 3- 4, 1997
37	Toward the Realization of the High-Definition Multi-Media Communication	Nov. 4- 6, 1997

International Symposium Organized by the Institute

	Title	Date
1	Intrinsic Josephson Effect and THz Plasma Oscillation in High T_c Superconductors	Feb.23-25, 1997
2	Design and Architecture of Information Processing Systems Based on The Brain Information Principle	Mar.16-18, 1998
3	Novel Techniques and Applications of Millimeter-Waves	Dec.14-16, 1998
4	The International Joint Conference on Silicon Epitaxy and Heterostructures	Sep.13-17, 1999
5	International Workshop on Photonic and Electromagnetic Crystal Structures	Mar.8-10, 2000
6	Physics and Application Spin Related Phenomena in Semiconductors	Sep.13-15, 2000
7	Rewriting in Proof and Computation	Oct.25-27, 2001
8	Nonlinear Theory and its Applications	Oct.28-Nov.1, 2001
9	New Paradigm VLSI Computing	Dec.12-14, 2002
10	Ultra High Density Spinic Storage System	Oct.23-24, 2003
11	3rd International Workshop on New Group IV (Si-Ge-C) Semiconductors	Oct.12-13, 2004
12	3rd International Workshop on High Freaqency Micromagnetic Devices and Materials (MMDM3)	Apr.11-12, 2005
13	4th International Conference on Silicon Epitaxy and Heterostructures (lCSl-4)	May 23-26, 2005
14	1st International WorkShop on New Group IV Semiconductor Nanoelectronics	May 27-28. 2005
15	GSIS International Symposium on Information Sciences of New Era: Brain, Mind and Society	Sep.26-27, 2005
16	The 1st RIEC International Workshop on Spintronics -Spin Transfer Phenomena-	Feb.8-9, 2006
17	4th International Workshop on High Frequency Micromagnetic Devices and Materials (MMDM4)	May 8,2006
18	4th International Conference on Physics and Applications of Spin-Related Phenomena in Semiconductors (PASPS-lV)	Aug.15-18,2006
19	2nd International Workshop on New Group IV Semiconductor Nanoelectronics	Oct.2-3,2006
20	2nd RIEC International Workshop on Spintronics	Feb.15-16,2007
21	Japan-China Joint Conference on acoustics, JCA2007	Jun.4-6,2007
22	International Conference on Discovery Science/ International Conference on Algorithmic Learning Theory	Oct.1-4,2007

23	The 3rd RIEC International Workshop on Spintronics	Oct. 31-Nov.1,2007
24	3rd International Workshop on New Group ⅣSemiconductor Nanoelectronics	Nov.8-9,2007
25	International Workshop on Nanostructures & Nanoelectronics	Nov.21-22,2007
26	The 18th International Symposium on Algorithms and Computation(ISAAC2007)	Dec.17-19,2007
27	International Interdisciplinary-Symposium on Gaseous and Liquid Plasmas (ISGLP 2008)	Sep.5-6,2008
28	4th International Workshop on New Group IV Semiconductor Nanoelectronics	Sep.25-27,2008
29	The 4th RIEC International Workshop on Spintronics	Oct.9-10,2008
30	Global Symposium on Millimeter Waves 2009 (GSMM2009)	Apr.20-22,2009
31	Mini R.I.E.C. workshop on multimodal perception	Apr.24,2009
32	The 4th International Symposium on Ultrafast Photonic Technologies	Aug.4-5,2009
33	PIMRC2009 Personal Indoor and Mobile Radio Communications Symposium 2009	Sep.13-16,2009
34	2nd RIEC-CNSI Workshop on Nanoelectronics,Spintronics and Photonics (5th RIEC Symposium on Spintronics)	Oct.22-23,2009
35	International Workshop on the principles and applications of spatial hearing 2009 (IWPASH2009)	Nov.11-13,2009
36	5th International Workshop on New Group IV Semiconductor Nanoelectronics	Jan.29-30,2010
37	6th RIEC International on Spintronics	Feb.5-6,2010
38	2nd International Workshop on Nanostructure & Nanoelectronics	Mar.11-12,2010
39	2nd RIEC International Symposium on Graphene Devices (ISGD2010)	Oct.27-29,2010
40	9th Japan-Korea Symposium on Surface Nanostructures	Nov.15-16,2010
41	The 7th RIEC International Workshop on Spintronics	Feb.3-4,2011
42	The 42nd RIEC International Symposium 12th International Multisensory Research Forum (IMRF2011)	Oct.17-20,2011
43	The 8th RIEC International Workshop on Spintronics	Feb.2-3,2012
44	The Sixth International Symposium on Medical, Bio- and Nano-Electronics	Mar.8,2012
45	3rd International Workshop on Nanostructures & Nanoelectronics	Mar.21-22,2012

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	
Chair	Prof. Ayumi Shinohara
Manager	Associate Prof. Eijiro Sumii

Systems Control	
Chair	Prof. Makoto Yoshizawa
Manager	Associate Prof. Noriyasu Homma

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

Spinics	
Chair	Prof. Hiroaki Muraoka
Manager	Associate Prof. Kenji Nakamura
Manager	Assistant Prof. Kousaku Miyake

New Paradigm Computing	
Chair	Prof. Michitaka Kameyama
Manager	Associate Prof. Masahide Abe

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

Brainware	
Chair	Prof. Koji Nakajima
Manager	Associate Prof. Shigeo Sato

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

Biocybernetics and Bioinformatics	
Chair	Prof. Satoshi Shioiri
Manager	Assistant Prof. Takeshi Obayashi

Nanoelectronics and Spintronics	
Chair	Prof. Junichi Murota
Manager	Associate Prof. Masao Sakuraba

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

7. International Activities

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

International academic exchange programs:

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

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

1	Acoustical Science and Technology
2	Applied Acoustics
3	Higher-order and Symbolic Computation
4	IEICE Electronics Express
5	IEICE Trans. on Electronics
6	Interdiscipliary Information Science
7	International Journal of Artificial Intelligence, Neural Networks, and Complex Problem Solving Technologies
8	International Journal of Computer Science and Network Security
9	International Journal of Energy, Information and Communications
10	International Journal of Information Sciences and Computer Engineering (IJISCE)

11	Journal of Ambient Intelligence and Humanized Computing
12	Journal of Communications and Networks
13	Journal of Magnetics Korean Magnetics Society
14	Journal of SPIN
15	Nature Communications
16	Nonlinear Theory and Its Applications, IEICE
17	NPG Asia Materials
18	Optical Fiber Technology
19	The Journal of Computer Animation and Virtual Worlds
20	Virtual Journal of Nanoscale Science and Technology

Recent international conferences programmed by a staff in RIEC:

1	10th Asia Pacific Conference on Computer Human Interaction(APCHI2012)
2	12th Joint MMM/Intermag Conference
3	15th International Symposium on the Physics of Semiconductors and Applications(ISPSA)
4	16th OptoElectronics and Communications Conference(OECC2011)
5	2011 Conference on Lasers and Electro-Optics(CLEO2011)
6	2011 Spintronics Workshop on LSI
7	2012 Conference on Lasers and Electro-Optics(CLEO2012)/Technical Program Committee Member
8	2nd CSIS International Symposium on Spintronics-based VLSIs and 8th RIEC International Workshop on Spintronics
9	5th International Workshop on Spin Currents
10	6th Advances in Computer Entertainment Technology Conference(ACE2010)
11	6th Annual ACM Conference on Interactive Tabletops and Surfaces(ITS2011)
12	6th International School and Conferece on Spintronics and Quantom Information Technology(SPINTECH6)
13	ACM Symposium on Virtual Reality Software and Technology(VRST)
14	ACSIN:11th International Conferrence on Atomically Controlled Surfaces, Interfaces and Nanostures
15	Asia Pacific Microwave Conference(APMC)

16	Asia Pacific Vision Conference 2013
17	AWAD：Asia-pacific Workshop on Fundamentals and Applications of Advanced Semiconductor Devices
18	CIMTC：4th International Conferrence on Smart Materials, Structures and Systems
19	ESSDERC：European Solid-State Device Research Conference
20	European Conference on Optical Communication(ECOC)
21	ICSFS：16th International Conferrence on Solid Films and Surfaces
22	IEEE International Symposium on Asynchronous Circuits and Systems
23	IEEE International Symposium on Multiple-Valued Logic
24	IEEE Symposium on 3D User Interfaces （3DUI）
25	International Multisensory Research Forum（IMRF)2011
26	International Multisensory Research Forum（IMRF）2012
27	International Quantum Electronics（IQEC）, Program Subcommittee Member for Quantum Information
28	International Symposium on Nonlinear Theory and its Applications
29	ISCS：International Symposium on Compound Semiconductors
30	Joint Polish-Japanese Workshop, Spintronics-from NewMaterials to Applications
31	OTST：Int. Conf on Optical Terahertz Science and Technology
32	SPIE International Conference on Defense, Security, and Sensing
33	SPIE Photonics West, Physics and Simulation of Optoelectronic Devices
34	The 11th IEEE International Conference on Cognitive Informatics and Cognitive Computing（ICCI*CC 2012）
35	The 15th International Conference on Network-Based Information Systems (NBiS-2012)
36	The 1st International Workshop on Smart Technologies for Energy,Information and Communication (STEIC2012)
37	The 2012 IEEE/WIC/ACM Intern. Joint Conference on Web Interlligence and Intelligent Agent Technology （WI-IAT2012）
38	The 22th Intern. Conf. Industrial & Engineering Applications of Artif. Intell. & Exp. Systems (IEA/AIE-2012)

39	The 5th International Symposium on Adaptive Motion of Animals and Machines
40	TWHM：Topical Workshop on Heterostructure Microelectronics

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

(2012.5.1)

Classification	Division	Laboratory for Nanoelectronics and Spintronics	Laboratory for Brainware sysystems	Research Center for 21st century Information Technology	Fundamental Technology Center	Administration Office	Total
Professors	19	3	3				25
Associate Professors	15	3					18
Assistant Professors	15	3	6				24
Research Fellows	19	2	1				22
Technical Officials					13	1	14
Administrative Officials						16	16
Total	68	11	10	0	13	17	119

2.Land and Buildings

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

(2012.5.1)

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

3.Budget

(Unit:1,000yen)

Financial Year	Personnel Expenditure	Supplies Expenditure	Research Grant			total
			Ministry of Education,Science and Culture	Partnership Between Universities and Industry	Leading-edge Research Promotion Fund	
2007	970,961	813,724	700,615	888,833	0	3,374,133
2008	879,481	953,000	694,883	1,069,832	0	3,597,196
2009	1,026,511	1,562,318	605,100	798,053	400,440	4,392,422
2010	777,776	735,496	418,680	962,712	1,034,827	3,929,491
2011	835,898	1,174,027	469,840	1,122,944	813,777	4,416,486

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.

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