RIEC Newsletter No.2

RIEC News

RIEC Newsletter
Research Institute of Electrical Communication
Tohoku University

TOHOKU UNIVERSITY

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Special ISSUE

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INSIDE the Laboratory

Research Institute of Electrical Communication
No.2
2015.3
Tohoku University

RIEC Main Building (Photo by Prof. Yoshifumi Kitamura)

Special ISSUE

Completion of RIEC Main Building

1. Introduction

RIEC's new building was finally completed in November 2014, more than 20 years after its initial planning. The building has been named as "RIEC Main Building", which is appropriate for its function.

The basic concept of the RIEC Main Building is "Providing an environment and functions to support world-leading frontier ICT research and education, as RIEC shall lead research in the field of electronic communications for a hundred years or more".

The completion was delayed for only about 4 months, in spite of the shortage of construction materials and workers by the East Japan Great Earthquake.

2. Characteristics and Features

The building has 5 stories and a basement level, but some portions are 6 stories. The total floor space is 13,513 m^2, which is one of the largest buildings in the Katahira Campus of Tohoku University.

The above-ground part of the building has a seismic isolation structure, resilient to big earthquakes and ordinary wind vibrations. There are special laboratories arranged inside, such as an electromagnetic anechoic chamber, a shielded room, an anechoic room and low vibration laboratories, that will provide R&D environments for accomplishing our mission of creating communications technologies that enrich people's lives.

Near to the entrance, an open atrium and lounge, an open seminar room, and an exhibition room are found.

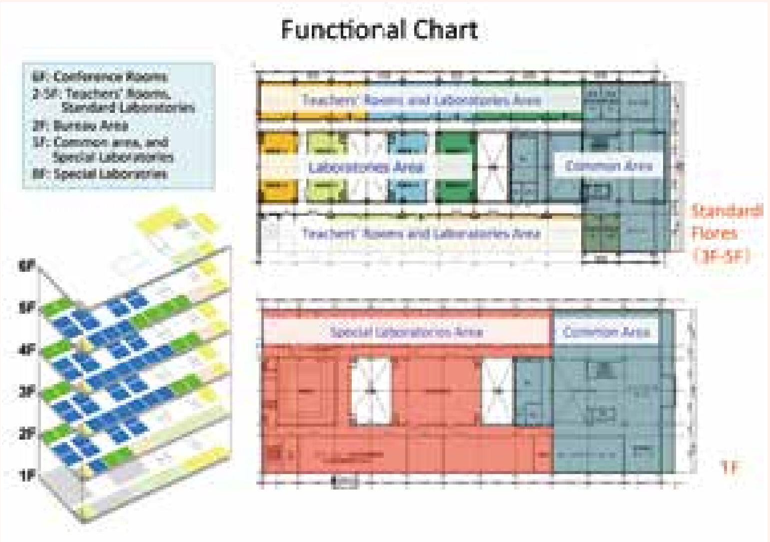
Large, medium, and small size conference rooms on the 6th floor and many seminar rooms on other floors have been arranged for enabling a variety of conventions or symposia. Graduate school lectures will also be held in this building.

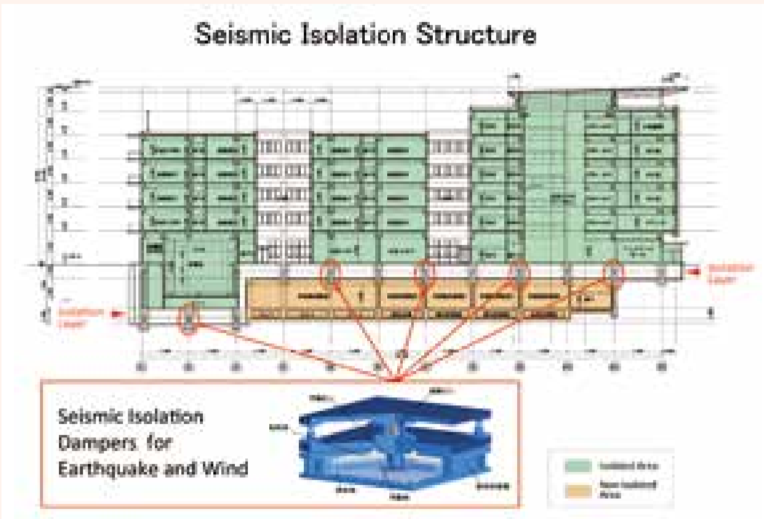
16 laboratories and the bureau section will move to the building by the end of March 2015, and will start research and education with renewed vigor.

3. Future Developments

In addition to the construction of the main building, RIEC has been planning to rebuild the existing Building No.2, where the remaining laboratories, library and facilities are to be moved.

The completion of the RIEC Main Building will definitely improve the environment for research and education, fostering the tradition of promoting cutting-edge R&D by all staff and students together.





TOPICS 1

Development of Highly-Functional Scanning Nonlinear Dielectric Microscopy (SNDM) and its Application to Electronic Devices

Professor Yasuo Cho

1. Introduction

Adopted as one of the national projects (S Class Grants-in-Aid for Scientific Research by MEXT and JSPS) in 2011, we have been conducting research on "Development of Highly-Functional Scanning Nonlinear Dielectric Microscopy (SNDM) and its Application to Electronic Devices". Our team consists of Assistant Professor Kohei Yamasue, Assistant Professor Yoshiomi Hiranaga, and myself. In this article, our main achievements and future plans are introduced.

2. Main Achievements

1) Development of new high performance SNDM

At the beginning of the research, we aimed to measure nonlinear dielectric signals at a fourth power polynomial of the electromagnetic field, but we have succeeded at measuring at a seventh power polynomial for semiconductor devices by using high sensitive probe. This measuring method enables us to analyze detailed characteristics of electronic devices, extends an epoch-making measurement system, and promotes the following research.

2) Enhancement of NC-SNDM

Based on the SNDM method, we have been developing an Ultra-High Vacuum Non-Contact SNDM (UHV-NC-SNDM). Adoption of a double vibration removal mechanism improved the stability of the equipment and atom-tracking technology enabled measurement of specific, single, surface atoms and molecules. For example, a Hydrogen adsorbed Si(111)-(7x7) surface was captured with this microscope. We also proposed a new measurement method for surface electrical potentials based on NC-SNDP (SNDP: Scanning Nonlinear Dielectric Potentiometry) and verified the performance of SNDP with the Si(111)-(7x7) surface. Moreover, we started investigations of the surface potential of Graphene using SNDP and made many discoveries.

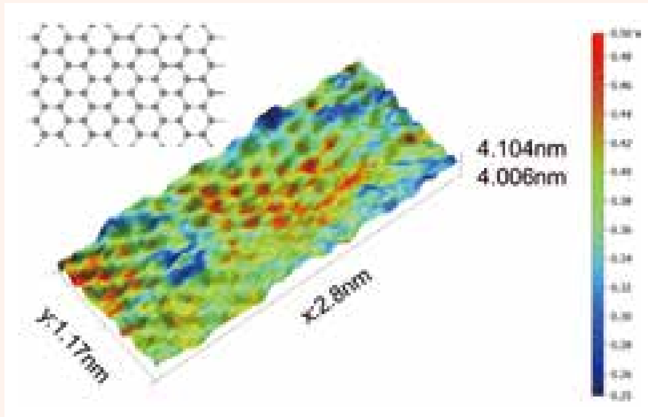


Figure 1 Surface Potential Visualization of Graphene on 4H-SiC(0001) using SNDP

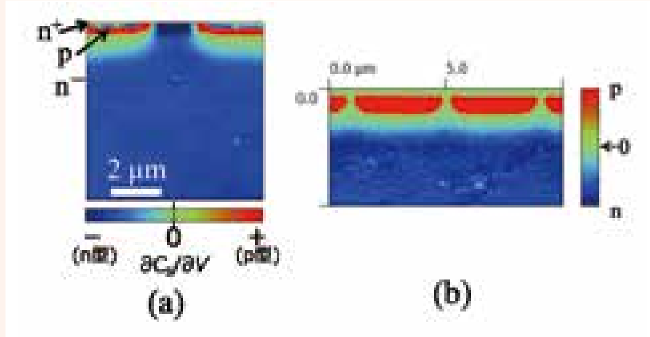


Figure 2 (a)Cross Section Dopant Profile of SiC-DMOSFET (b)Visualization of guard ring of SiC-DMOSFET

3) Study of an Ultra-high density ferroelectric recording system

We have recently conducted high-density dot recording experiments on a hard disk drive (HDD) type ferroelectric recording system. Single crystal $LiTaO_3$ was used in this case as the recording medium. The results indicate that a memory density of 3.44 Tbit/inch^2 may be realized when two-dimensional recording is achieved.

4) Application of SNDM measurement to semiconductor devices

By using SNDM, we have confirmed outstanding improvement of dopant profile analysis in semiconductor devices. We also succeeded in visualization of the dopant profile of cross-sectioned SiC-DMOSFET and its guard ring. This promotes the development of next generation power devices.

3. Future Plan

We are planning to expand our measuring method to the evaluation of many kinds of electronic devices following the success of the SiC power device dopant profile analysis. Estimation of Graphene and Graphene devices will be also in our scope using UHV-NC-SNDM. SNDP is not only applicable to areas as KPFM but also to dipole electrical potential measurements. In addition to the current achievements, we are confident we will overcome most of these challenges by the end of the project in March 2016.

TOPICS 2

Ultrahigh-Speed / Spectrally-Efficient Coherent Optical Transmission

Laboratory of Ultrahigh-Speed Optical Communication, Associate Professor **Toshihiko Hirooka**

According to a report from the Japanese Ministry of Internal Affairs and Communications, the volume of data traffic transmitted in Japan reached as high as 1 Tbit/s in 2009, and it is still increasing by 40% annually. The growing demand for a larger transmission capacity in backbone optical networks has made it important to increase the bit rate per channel and spectral efficiency simultaneously to take full advantage of the available bandwidth resources.

To meet this goal, we have developed an ultrahigh-speed and highly spectrally efficient transmission system, in which data are encoded on the amplitude and phase of coherent optical pulses and then time-division multiplexed in the optical domain. Figure 1 shows an overview of the transmission system. This scheme features an ultrahigh bit rate beyond the limit of electronics as well as a large increase in spectral efficiency due to the adoption of multi-level quadrature amplitude modulation (QAM), which results in highly efficient bandwidth utilization and reduced power consumption. By employing 64 QAM modulation in 10 GHz coherent Gaussian pulses and multiplexing them to 160 Gsymbol/s, we achieved a single-channel bit rate of 1.92 Tbit/s and successfully transmitted a signal over 150 km. Despite such an ultrahigh bit rate, the system involves only electronic devices operating at 10 GHz and passive optical devices, and therefore the power consumption can be greatly reduced.

It has been well known that with conventional Gaussian or sech short optical pulses, it is difficult to improve the spectral efficiency even with higher-order QAM. This is because these short pulses inevitably occupy a large bandwidth. To overcome this bottleneck, we proposed a novel high-speed and highly spectrally efficient transmission scheme using an “optical Nyquist pulse.” An optical Nyquist pulse and its comparison with conventional pulses are shown in Fig. 2. Unlike conventional pulses, it has a periodically oscillating tail in the time domain and does not decay rapidly. This means that the bandwidth of the Nyquist pulses is much smaller than that of Gaussian or sech short pulses. It is important to note that, by setting the bit interval equal to the oscillation period, the multiplexed pulses do not interfere with each other even when they strongly overlap. As a result, the signal bandwidth can be greatly reduced. Non-coherent Nyquist pulses have already been applied to single-channel 1.28 Tbit/s-525 km transmission, for which tolerances to chromatic dispersion and polarization-mode dispersion have been greatly improved. As a future prospect, the combination of high-order QAM and high-speed coherent Nyquist pulses is expected to constitute the ultimate goal as regards maximum transmission capacity with the available bandwidth resource.

This research was awarded a grant by the “Funding Program for Next Generation World-Leading Researchers (NEXT Program)” launched by the Council for Science and Technology Policy (CSTP). I would like to thank Prof. Masataka Nakazawa and the members of the laboratory for their help and contribution to this work.

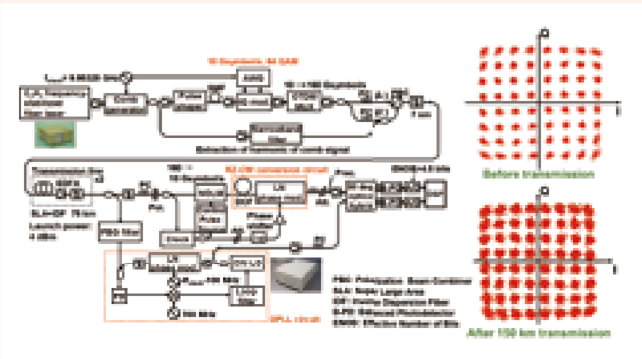


Figure 1 Single-channel 1.92Tbit/s, 64QAM ultrahigh-speed multi-level transmission experiment.

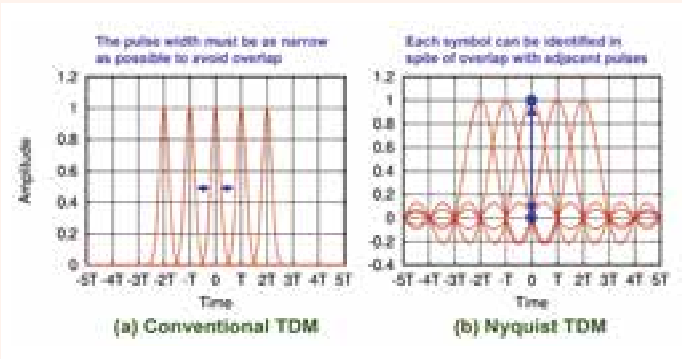


Figure 2 Comparison between (a) conventional TDM and (b) proposed Nyquist TDM transmission.

INSIDE the Laboratory

Laboratory for Nanoelectronics and Spintronics

Semiconductor Spintronics Laboratory

Hideo Ohno, Professor
Shun Kanai, Assistant professor
URL: http://www.ohno.riec.tohoku.ac.jp/

There are currently 22 members in this laboratory; Prof. Hideo Ohno, Assistant prof. Shun Kanai, two postdoctoral fellows, one research assistant, one secretary, five Ph. D. candidates, five Master course students, four undergraduate-school students, and two research students. We collaborate with members of the WPI-Advanced Institute for Materials Research (WPI-AIMR), the Center for Spintronics Integrated Systems (CSIS), and the Center for Innovative Integrated Electronics Systems (CIES) for the research on Spintronics. There are six members from abroad; China, Taiwan, France, India, Philippines, and Russia.

Spintronics, where both the electron spin and charge degrees of freedom are controlled, is attracting much attention not only because it is a frontier of condensed matter physics but also because it provides cutting edge technology not attainable without using the spin degree of freedom. We work on both semiconductor spintronics and metal spintronics. In semiconductor spintronics, our research focuses on the spin-dependent properties of ferromagnetic semiconductors as well as the spin phenomena in non-magnetic semiconductors. Our work has resulted in new concepts of condensed matter physics as well as in demonstrations of proof-of-concept spintronics devices with new functionalities. These concepts are now transferred to metallic spintronics devices. Metal spintronics is also important in its own right. Here we investigate a number of phenomena that are critical to near future integrated circuit technology. They include the giant variation of electric resistance according to the magnetization configuration, magnetization switching with spin transfer in ferromagnetic metal/ insulator/ ferromagnetic metal (magnetic tunnel junction structure) structures with diameters down to 11 nanometers ($=11\times10^{-9}$ m), non-magnetic metal/ times symbol ferromagnetic metal structures, and electrical manipulation of the interface magnetic anisotropy of ferromagnetic metals/ insulators. These technologies are now being applied to stand-by power free, ultralow power consumption, non-volatile very large scale integrated circuits (VLSI) through collaborative joint research and development.

Human Information Systems Division

Visual Cognition and Systems Laboratory

Satoshi Shioiri, Professor
Ichiro Kuriki, Associate Professor **Kazumichi Matsumiya,** Associate Professor
URL: http://www.riec.tohoku.ac.jp/lab/shioiri/index-e.html

It is not difficult to imagine how living becomes hard if we lose our vision and there is no doubt of the importance of vision in life. Understanding the brain functions for vision is one of the most important issues in science and technology to improve the quality of human life and society. Since the foundation of the laboratory in 2005, we (Satoshi Shioiri, Ichiro Kuriki and Kazumichi Matsumiya) have been working on vision and vision-related brain functions both in science and engineering fields with brilliant students from Japan and other countries (China, Sweden, Thailand, USA, Taiwan and Venezuela).

We investigate the human brain through visual functions using psychophysics, brain imaging and computer simulations, and apply the knowledge to human engineering and image engineering. Our research field covers visual spatial perception, 3D perception, color vision, visual attention and visual-haptic integration. The following is a list of recent research topics.

- Measurements and modeling of characteristics of visual attention.
- Investigation of motion, depth and color perception at early and middle level visual processes.
- Representation of color information in the human brain
- Separation and integration of visual information in the human brain
- Cross modal processing between visual and haptic information.

One of our recent findings is the interaction of haptic and visual information at a visual process specific to peripersonal space[1]. We reported a visual motion aftereffect (MAE) that shows spatial selectivity in hand-centered coordinates. The MAE is an illusion of visual motion resulting from adaptation to a moving pattern and normally occurs with retinal overlap between adaptor and test. MAEs occurred without retinal overlap between the adaptor and test when the adaptor and test were presented at the same position relative to a hand. This suggests that the visual system has a perceptual representation of the space encoded in body-part-centered coordinates, which is useful for guiding movements of one’ s body parts.

1) Matsumiya K, Shioiri S, Current Biology 24 (2), 165-169, 2014.

INSIDE the Laboratory

Information Devices Division

Nano-Photoelectronics Laboratory

Yoichi Uehara, Professor
Satoshi Katano, Associate Professor
URL: http://www.nanophoto.riec.tohoku.ac.jp/

The Nano-Photoelectronics Laboratory of Prof. Yoichi Uehara and Assoc. Prof. Satoshi Katano conducts research on the physical and chemical phenomena that take place in nanometer-scale regions and their application in optoelectronic devices. In particular, we use a scanning tunneling microscopy (STM) to visualize the individual atoms and molecules. This enables us to reveal the optical responses of the nano materials with atomic-scale precision through the examination of the light emission induced by the injection of tunneling electrons from the STM tip (STM-LE).

The research activities have been carried out with graduate and undergraduate students from the department of electronic engineering, Tohoku University. Currently, one student from China (graduated from Zhejiang University) attends the graduate course to study nanomaterial engineering. Some of our recent achievements are briefly summarized as follows.

1. STM-LE spectroscopy with picosecond time resolution

We have succeeded in the development of a novel surface probing method that can achieve ultimate spatial and temporal resolutions. This has been demonstrated by irradiation of the pulse laser in the STM junction. The laser-induced STM-LE shows a temporal behavior whose duration coincides with the incident laser pulse. The present result opens a new way toward achievement of high-resolution optical spectroscopy in the time, space and energy domains.

2. Vibrational analysis of an individual nanostructure using STM-LE

Identification of the chemical composition of a single molecule is considered to be a central issue for the fabrication of nano-molecular devices. Recently, we have demonstrated that the vibrational excitation of a single molecule can be detected by STM-LE spectroscopy in the visible range. We are also interested in STM-LE measurements in the THz spectral range, which must be utilized as a tool for the direct observation of the vibrational resonance energy.

Broadband Engineering Division

Ultra-Broadband Signal Processing Laboratory

Taiichi Otsuji, Professor **Tetsuya Suemitsu,** Associate Professor
Stephane Albon Boubanga-Tombet, Associate Professor
URL: http://www.otsuji.riec.tohoku.ac.jp/

We are responsible for exploring the devices/circuits/systems utilizing terahertz (THz) electromagnetic waves. The technical staff includes Associate Professors Tetsuya Suemitsu and Stephane Albon Boubanga-Tombet (Congolese), Assistant Professors Akira Satou and Susumu Takabayashi, Visiting Professor Victor Ryzhii (Russian), Post-Doctoral Fellows Adrian Dobroiu (Rumanian) and Takayuki Watanabe, Research Assistant Kayo Ueno, and Professor Taiichi Otsuji. Two doctor-course and nine master-course students in the graduate school, and three bachelor-course students in the undergraduate school are studying in our laboratory, including four foreign students (Ms. Deepika Yadav (DC-1) from India, Ms. Mastra binti Hussin (MC-2) from Malaysia, Mr. Stevanus Arnold (MC-1) from Indonesia, and Mr. Christian Koguchi (BC-3, an undergraduate exchange student from UCSD, USA). The laboratory is full of international atmosphere, and all the members are always enjoying the wide variety of cultural, academic, and lifestyle exchange/interaction.

THz waves, situated between radio waves and light waves, attract attention in various scenes such as safety, security, and ultra-broadband wireless communications. In order to realize these industrial real-world applications and to break through conventional technological limitations, we are developing novel THz functional devices that can be integrated and can operate at room temperature. Creation of new types of graphene-based THz lasers, development of THz detectors/emitters using two-dimensional plasmons in semiconductor quantum wells, and ultrafast transistors and ICs are the primary concerns of our research activities in international collaborations with Japanese, US, Russian, French, Spanish, and German scientists under the financial support of JSPS Specially Promoting Research, JST-CREST, JST-ANR Japan-France Strategic International Collaborative Research Project, JSPS Japan-Russia Bilateral Joint Research Project, Tohoku Univ. RIEC Nation-Wide Japan-Spain Joint Project, and Tohoku Univ. RIEC-RLE Project, Japan, and NSF-PIRE TeraNano Program, USA. Among these international collaborations we are actively promoting the exchange of scientists and students every year. For more information, please visit our homepage.

Laboratory for Brainware Systems

New Paradigm VLSI System Laboratory

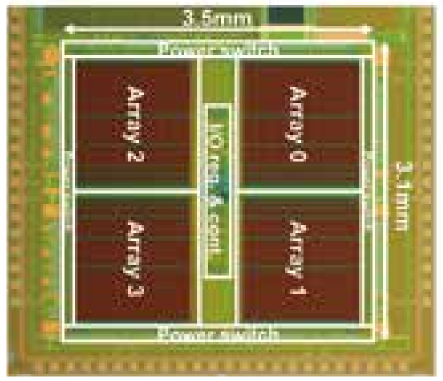
Takahiro Hanyu, Professor
Masanori Natsui, Associate Professor
URL: http://www.ngc.riec.tohoku.ac.jp/en/

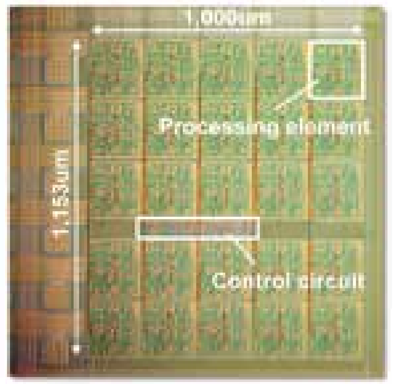
Rapid progress in the recent deep submicron regime has led to the capability to realize giga-scaled embedded systems on a chip (SoC), while the communication bottleneck between memory and logic modules has increasingly become a serious problem. In addition, power dissipation and device-characteristic variation have also been emerging problems in the recent very large-scaled integration (VLSI) chip. In order to solve these recent VLSI problems, which cause performance and reliability degradation, our research group focuses on a "new-paradigm VLSI computing" concept that investigates the optimal design through all the VLSI design layers from a device/material design level to an application-oriented algorithm level.

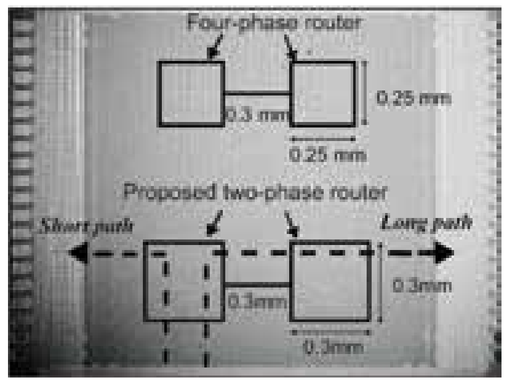
As one of the latest research activities, we are focusing on a new VLSI architecture called "nonvolatile logic-in-memory (NV-LIM) architecture" and its design methodology. In this architecture, storage functions are distributed over a logic-circuit plane, which greatly reduces global wiring. To implement an NV-LIM LSI compactly, we utilize multi-functional and nonvolatile devices such as ferroelectric devices, magnetic tunnel junction (MTJ) devices and phase-change devices. We have proposed various applications based on NV-LIM architecture such as a ternary content-addressable memory (TCAM) chip (Fig.1) and a motion-vector prediction chip (Fig.2), and have confirmed the potential capability of NV-LIM LSI through fabrication and measurement under a national research project called "FIRST program" (project leader: Prof. Hideo Ohno). These results were announced at top-level international conferences on solid-state circuits such as ISSCC and VLSI Symposium, which clearly indicates the extremely high impact of our research activity on the related research communities.

We are also focusing on another challenging research subject concerning a new-paradigm VLSI computing system, that is, asynchronous data-transfer technique. Asynchronous design, where the timing constraint is limited locally, is one possible approach to solving today' s serious interconnection problem, while maintaining low power dissipation, high speed and robustness. We have confirmed the capability of the proposed asynchronous system through the design and fabrication of concrete examples such as a low-energy asynchronous interleaver for clockless fully parallel low-density parity-check (LDPC) decoding and a delay-insensitive asynchronous network-on-chip (NoC) router (Fig. 3), whose results were published in prestigious academic journals such as IEEE TCAS-I and IEEE Computer.

VLSI processors and their application to a wide range of "smart" electronics systems, where VLSI processors are used as a "brain" for intelligent control like human beings, are key components in the recent information communication technology (ICT) society. In this research division, we explore a path towards a new-paradigm VLSI processor beyond brain, utilizing novel device technologies and new-paradigm circuit architecture.







90nm CMOS/70nm p-MTJ technologies

0.13μm CMOS technology

Figure 1 Nonvolatile TCAM Chip:
Power supply at unmatched modules using perpendicular MTJ devices can be turned off. The search energy becomes 1/100 in comparison with that of the CPU implementation.

Figure 2 Nonvolatile Motion-Vector Prediction Chip:
The chip is designed by using automated design tools for nonvolatile LSI. 75% of wasted power dissipation is eliminated by utilizing fine-grained nonvolatile power gating.

Figure 3 Asynchronous NoC Router Chip:
High-throughput compact delay-insensitive NoC router is fabricated based on an asynchronous-circuit aware packet structure.

Commendations & Awards

●Assist. Prof. Naoya Onizawa and Prof. Takahiro Hanyu
/ ASYNC2014 Best Paper Finalist
"A Compact Soft-Error Tolerant Asynchronous TCAM Based on a Transistor/Magnetic-Tunnel-Junction Hybrid Dual-Rail Word Structure" 14 May 2014

●Prof. Masataka Nakazawa
/ Charles Hard Townes Award
"For seminal contributions to the science and applications of ultrafast optics and ultrastable narrow-linewidth lasers" 10 Jun. 2014

●Assist. Prof. Dai Owaki and Prof. Akio Ishiguro
/ CLAWAR Association Best Technical Paper Award (Highly Commended paper award)
"CPG-based control of bipedal walking by exploiting plantar sensation" 22 Jul. 2014

●Mr. Yusuke Hachiya, 1st year student of master course at Kinoshita- Kitagata Lab.
/ 2014 IEEE 3rd Global Conference on Consumer Electronics (GCCE 2014), Outstanding Paper Student Award
"Cooperation Mechanism of Heterogeneous Contents in User-Oriented Information Delivery System" 9 Oct. 2014

●Prof. Masataka Nakazawa and Assoc. Prof. Masato Yoshida
/ International Wire & Cable Symposium, Jack Spergel Memorial Award
"Investigation of the Influence of Fusion Splice on Crosstalk Properties of Multicore Fiber" 10 Nov. 2014

●Ms. Y. Wang, research fellow at Nakazawa Lab.
/ ACP (Asian Communications and Photonics Conference) 2014, IEEE Photonics Society Best Student Paper Awards (1st Grade Awards)
"140 Gbit/s, 128 QAM LD-based Coherent Transmission over 150 km with an Injection-locked Homodyne Detection Technique" 13 Nov. 2014

●Prof. Shuzo Kato
/ IEEE Life Fellow 1 Jan. 2015

International Symposia organized by the Institute

Title	Date	Venue
12th RIEC International Workshop on Spintronics	25 - 27 Jun. 2014	RIEC Nano-Spin Lab. Build.
The IEEE International Conference on Microwave Magnetics 2014	29 Jun. - 2 Jul. 2014	Sendai International Center
RIEC International Symposium on Perception and Communication	24 Jul. 2014	RIEC Nano-Spin Lab. Build.
APMC 2014 (2014 Asia-Pacific Microwave Conference)	4 - 7 Nov. 2014	Sendai International Center
The 3rd RIEC International Symposium on Brain Functions and Brain Computer	18 - 19 Feb. 2015	RIEC Nano-Spin Lab. Build.
International Symposium on Brainware LSI	2 - 3 Mar. 2015	RIEC
The 9th International Symposium on Medical, Bio- and Nano-Electronics	2 - 3 Mar. 2015	RIEC Nano-Spin Lab. Build.
The 6th International Workshop on Nanostructures and Nanoelectronics	3 - 4 Mar. 2015	RIEC Nano-Spin Lab. Build.
RIEC International Symposium on Vision and Cognition	20 Mar. 2015	RIEC

Editor's Note

The year 2015 is not only the grand opening of the new RIEC Main Building, but also the 80th Anniversary of our Institute. Prof. Hideo Ohno, Director of RIEC, strongly encouraged RIEC members at the new year ceremony, referring to the old saying 'Pour new wine into fresh wineskins' . (Y.S.)

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