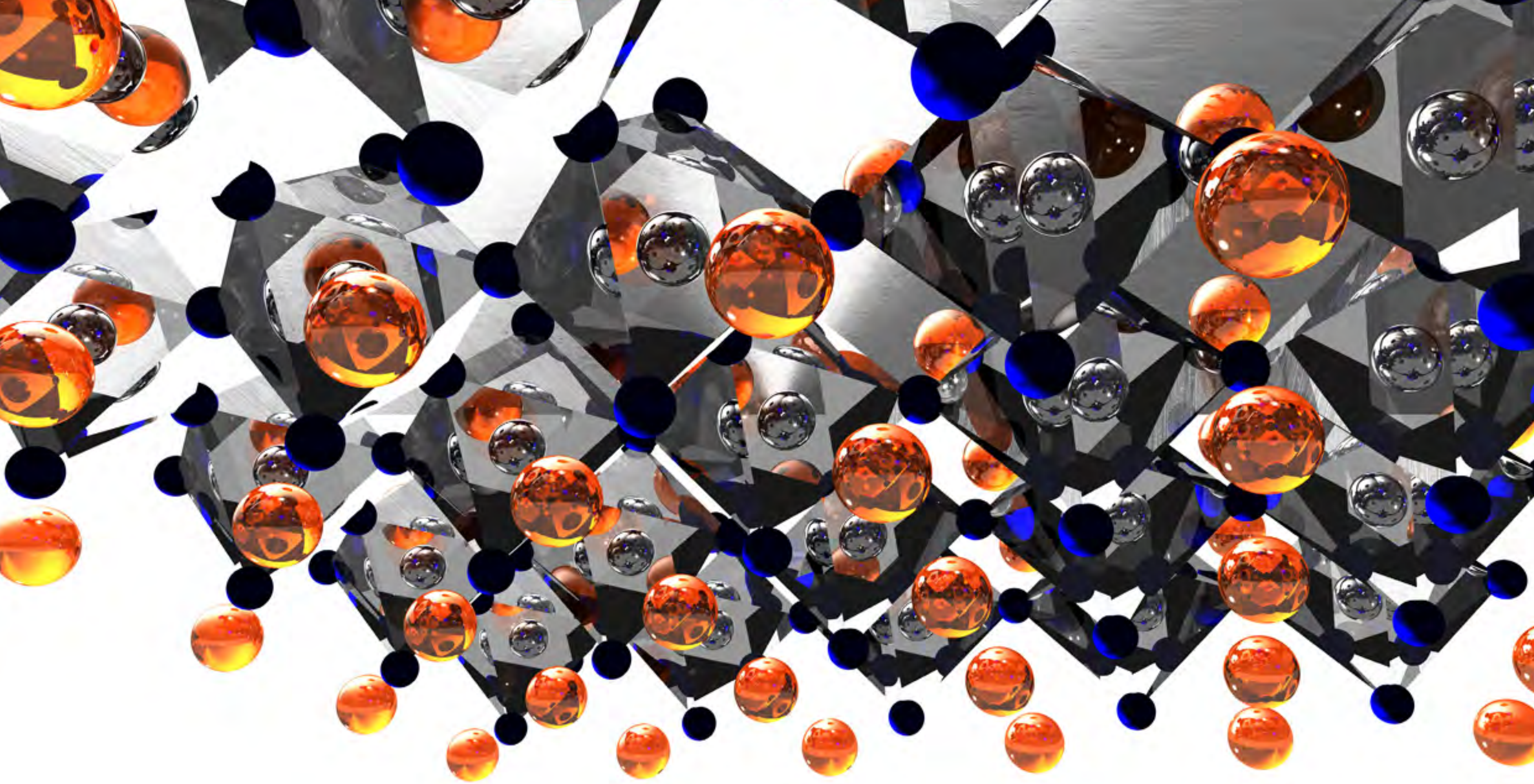


NTT Basic Research Laboratories

Annual Report 2019

NTT BASIC RESEARCH LABORATORIES

Message from the Director

We at NTT Basic Research Laboratories (BRL) are extremely grateful for your interest and support with respect to our research activities.
BRL's mission is to promote progress in science and innovations in leading-edge technology to advance NTT's business. To achieve this mission, researchers in various fields, including physics, chemistry, biology, mathematics, electronics, informatics, and medicine, conduct basic research on materials science, physical science, and optical science.
Our management principle is based on an "open door" policy. For example, we are collaborating with many universities and research institutes all over the world as well as other NTT laboratories. We also organize several workshops and ISNTT, an international conference held at the Atsugi R&D Center, to disseminate our research output and hear the opinions of the attendees. In addition, we hold the NTT-BRL School, which is dedicated to the development of young researchers around the world. To this school, we invite distinguished researchers from around the world as lecturers to give young researchers, including those at NTT, the opportunity to learn from the foremost authorities and share ideas with them.
Through these activities, we will continue to succeed in promoting advances in science and innovations in leading-edge technology for NTT's business. Your continued support will be greatly appreciated.

Director of NTT Basic Research Laboratories

Front image:

Perovskite oxides

Complex oxides, which include two or more cations in a unit cell, especially those with the perovskite-related structures offer a rich variety of functionalities such as superconductivity, magnetism, and dielectricity. They have been extensively investigated from both scientific and technological viewpoints. Researchers of NTT Basic Research Laboratories have succeeded in preparing the world's best-quality thin films of such materials, including trailblazing superconductors and magnetic materials beyond conventional concepts. They use a unique oxide thin-film growth technique that they have developed over many years, with which atoms can be supplied ad arbitrium in vacuum.

Activity Report

Advisory Board

The NTT BRL Advisory Board, which was first convened in 2001, held its 10th meeting on January 30 - 31, 2019. The aim of the Advisory Board is to provide an objective evaluation of our research plans and activities to enable us to employ strategic management in a timely manner. At this meeting, the BRL researchers had a lunch and a poster session with the board members, where they had chances to present their researches to the board members in a casual atmosphere.

ISNTT

International School and Symposium on Nanoscale Transport and phoTonics

The international school and symposium ISNTT, biennially held in NTT-BRL, brings together leading scientists, researchers, and graduate students to share their latest research accomplishments and discoveries related to the physics and technology of nanoscale structures.
ISNTT encourages frank and open technical discussions on recent breakthroughs and advances in related research.
In 2019, we had 135 oral/poster presentations, including keynote talks by Prof. Klaus von Klitzing (Max Planck Institute) and Prof. Yasunobu Nakamura (University of Tokyo/Riken), and 19 invited talks.

NTT-BRL School

The NTT-BRL School is held to foster the development of young researchers and promote the international visibility of NTT.
In 2019, on the subject “Quantum Hybrid System”, we had lectures by Prof. Göran Johansson and Prof. Per Delsing (both from Chalmers University of Technology) and by Dr. Kouichi Semba (National Institute of Communications Technology). The program also included laboratory tours and a poster session.

International Symposium CNC

Coherent Network Computing

The International Symposium on Coherent Network Computing (CNC) was held from March 18 to 20, 2019, co-sponsored by the Japan Science and Technology Agency (JST) and NTT Basic Research Laboratories. A total of 138 researchers attended and discussed various topics on network computing based on various physical systems and algorithms, such as coherent Ising machines, quantum annealing, and combinatorial optimization problems.

Organization

NTT Basic Research Laboratories

Director
Hideki Gotoh

Research Planning Section

Executive Manager
Kazuhide Kumakura

Materials Science Laboratory

Executive Manager
Hideki Yamamoto

→ P5

- Thin-Film Materials Research Group
- Low- Dimensional Nanomaterials Research Group
- Molecular and Bio Science Research Group

Physical Science Laboratory

Executive Manager
Akira Fujiwara

→ P7

- Nanodevices Research Group
- Nanomechanics Research Group
- Superconducting Quantum Circuit Research Group
- Quantum Solid State Physics Research Group

Optical Science Laboratory

Executive Manager
Hideki Gotoh

→ P9

- Quantum Optical State Control Research Group
- Theoretical Quantum Physics Research Group
- Quantum Optical Physics Research Group
- Photonic Nano-Structure Research Group

The population data of NTT-BRL members

- Researchers (Foreign Researchers)…99(12)
- Research Associate/Specialist…10
- Joint Researcher…11
- International Interns…21*
- Domestic Interns…24*
- Invited professor…2*
- Guest Researchers…4*

*…Jan. to Dec. 2019 total

As of Dec. 31, 2019

10th Advisory Board Meeting (January 30, 2019)

Advisory Board

Affiliation is as of Jan. 30 , 2019

Forschungszentrum Jülich, Germany
Prof. Andreas Offenhäusser

University of Twente, The Netherlands
Prof. Dave H.A. Blank

Chalmers University of Technology, Sweden
Prof. Per Delsing

Laboratoire Kastler Brossel, France
Prof. Elisabeth Giacobino

CEA Saclay, France
Prof. Christian Glattli

Max-Planck-Institut für Festkörperforschung, Germany
Prof. Klaus von Klitzing

University of Illinois at Urbana-Champaign, U.S.A.
Prof. Sir Anthony J. Leggett

The University of Texas at Austin, U.S.A.
Prof. Allan H. MacDonald

Imperial College London, U.K.
Prof. Sir Peter Knight

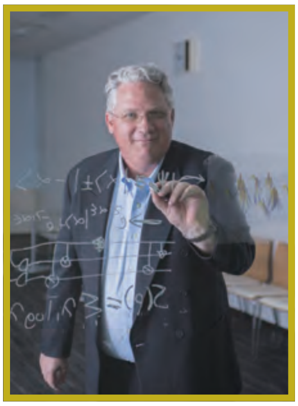
Nanophotonics Center

Project Manager
Masaya Notomi

P11

Research Center for Theoretical Quantum Physics

Project Manager
William John Munro



P11

Bio-Medical Informatics Research Center

Project Manager
Hiroshi Nakashima

P11

Research Professors

Kwansei Gakuin University
Prof. Hiroki Hibino

Medical & Health Informatics Laboratories (MEI Lab),
NTT Research, Inc.
Prof. Hitonobu Tomoike

Physics & Informatics Laboratories (PHI Lab),
NTT Research, Inc.
Prof. Yoshihisa Yamamoto

Materials Science Laboratory

Overview

The aim of the Materials Science Laboratory is to contribute to progress in materials science and to revolutionize information communication technology by creating novel materials and functions through materials design and arrangement control at the atomic and molecular levels. The research groups that constitute this laboratory are investigating a wide range of materials including typical semiconductors such as GaAs and GaN, two-dimensional materials such as graphene, oxide superconductors and magnetic materials, conductive polymers, and biological soft materials. We are conducting innovative materials research based on advanced thin-film growth technologies and high-precision and high-resolution measurements of structures and properties along with theoretical studies as well as Materials Informatics.

Group Introduction

Thin-Film Materials Research Group

Novel Semiconductor Devices

Creation of light-emitting devices over a wide range from DUV to NIR, high-efficiency energy creation/conversion devices, and novel multifunctional (optical, electric, and spintronic) devices

Low-Dimensional Nanomaterials Research Group

2D atomic-layer Materials

Creation of ultimately thin functional atomic-layer materials for next-generation electronics

Complex Oxide Thin Films

Creation of trailblazing superconductors and magnetic materials beyond conventional concepts

Molecular and Bio Science Research Group

Biocompatible Soft Materials

Development and application of soft material composites for measurement of deep biological information

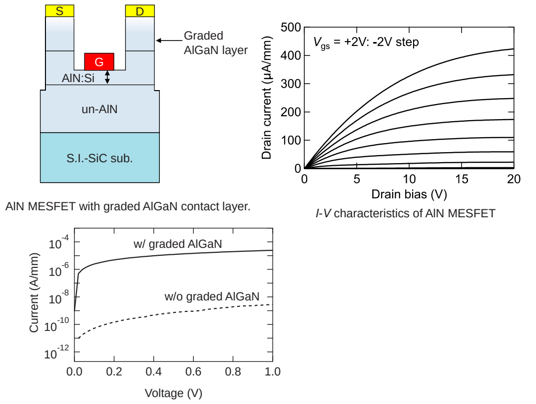
Interface Interaction

Creation of biodevices and soft robots
by controlling interactions at cell/cell and cell/non-cell substance interfaces

Biosensing

On-chip biosensing devices for biomolecular analysis at molecular scale

Multi-source molecular beam epitaxy apparatus: an enabling technology for high-quality thin films of complex oxides/nitrides, which is also exploited as a synthesis method *sui generis* for novel superconductors and magnetic materials.

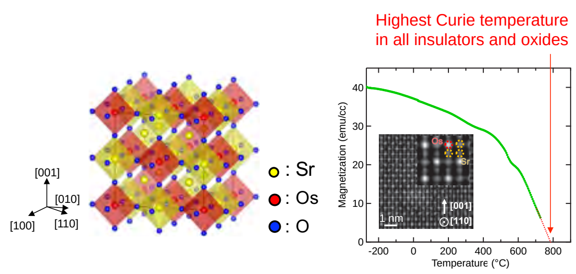


Ohmic contact characteristics for n-AlN with and without graded AlGaN

Ohmic Contact to n-type AlN Using Graded-AlGaN Contact Layers and Operation of AlN MESFETs

The ultrawide bandgap semiconductor AlN has a breakdown electric field about 40 times larger than Si's and about four times larger than GaN and SiC's, which makes it attractive for high-voltage power applications. However, the large barrier height between AlN and metals makes it difficult to form ohmic contacts. We achieved good ohmic contacts to n-type AlN by forming a compositionally graded-AlGaN contact layer in which negative polarization charge density is controlled. As a result, we demonstrated the operation of n-type AlN-MESFETs.

M. Hiroki and K. Kumakura, Appl. Phys. Lett. 115, 192104 (2019).

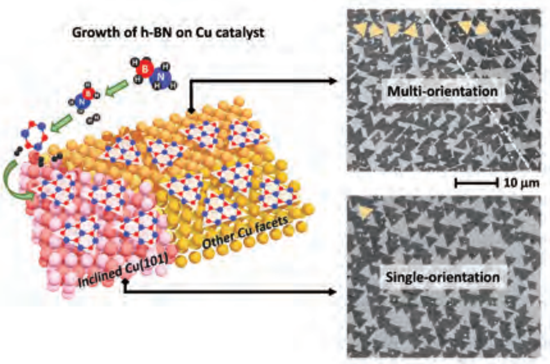


(Left) Crystal structure of Sr_3OsO_6. (Right) Magnetization vs. temperature curve. (Inset in right) Electron microscopy image of Sr_3OsO_6.

Creation of Novel Ferromagnetic Insulator Sr_3OsO_6

We synthesized Sr_3OsO_6, a novel insulator that exhibits ferromagnetism above 780 °C, which surpasses the Curie temperature record among insulators for the first time in 88 years. Unlike most conventional magnetic materials, Sr_3OsO_6 is free from Fe (iron) and Co (cobalt) and hence paves a new way to the exploration and development of other novel magnetic materials. This brand-new material is promising for high-performance magnetic devices that can be stably operated at high temperatures (room temperature to 250 °C).

Y. K. Wakabayashi, Y. Krockenberger, N. Tsujimoto, T. Boykin, S. Tsuneyuki, Y. Taniyasu, and H. Yamamoto, Nat. Commun. 10, 535 (2019).

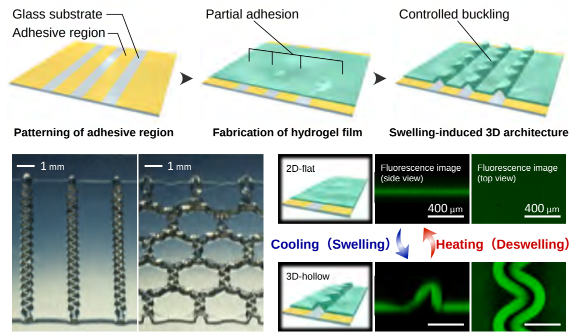


Schematic of CVD growth of h-BN on Cu. Single-orientation and multi-orientation h-BN grown on inclined Cu (101) and other facets, respectively.

Single-orientation Growth of 2D Hexagonal Boron Nitride

Controlling the crystallographic orientation of 2D materials is essential for tailoring their properties and engineering 2D functional devices. Here we demonstrated that hexagonal boron nitride (h-BN), an ideal 2D dielectric, has a single orientation on inclined Cu (1 0 1) surfaces, where the Cu planes are tilted from the (1 0 1) facet around specific in-plane axes. The single-orientation h-BN is free of wrinkles and exhibits electric performance with excellent homogeneity on a large scale. These findings will pave the way for the integration of 2D functional devices on large-scale substrates.

S. Wang, A. E. Dearle, M. Maruyama, Y. Ogawa, S. Okada, H. Hibino, and Y. Taniyasu, Adv. Mater. 31, 1900880 (2019).



(upper) 3D architecture formation based on swelling pressure of hydrogel film. (lower left) Buckling at an arbitrary position. (lower right) Reversible switching of 3D hydrogel architecture (2D flat- 3D hollow) utilizing temperature responsive gels.

3D Hydrogel Architecture Induced by Swelling

Hydrogels, which consist of a polymer network and water, show characteristic properties such as biocompatibility and volume changeability due to swelling. In this research, we established a method for creating 3D hydrogel architectures at an arbitrary position on hydrogel/glass substrate composites to which the desired interface is adhered. By introducing a stimuli-responsive unit into the hydrogel, we successfully demonstrated reversible switching between 2D flat and 3D hollow architectures. This dynamic tuning of a 3D hydrogel architecture has great potential for 3D cell culture substrates and soft actuators.

R. Takahashi, H. Miyazako, A. Tanaka, and Y. Ueno, ACS Appl. Mater. Interfaces 11, 28267 (2019).

Physical Science Laboratory

Overview

The Physical Science Laboratory aims to develop semiconductor- and superconductor-based devices and hybrid-type devices, which will have a revolutionary impact on the ICT society of the future. We are using high-quality crystal growth and nanofabrication techniques to explore novel properties that could lead to nanodevices for ultimate electronics and novel information processing applications based on new degrees of freedom such as single electrons, mechanical oscillations, quantum coherent states, electron correlation, and spins.

Group Introduction

Nanodevice Research Group

Single-electron Devices for Ultimate Electronics

Highly accurate, highly sensitive, and low-power devices based on single charge transfer and detection

Nanodevices with Novel Functions

Novel and high performance nanodevices based on silicon and hybrid materials

Nanomechanics Research Group

Semiconductor Opto/electromechanics

Novel devices using mechanical functionality in semiconductor fine structures

Phonon Manipulation

Propagation control of acoustic waves using artificial structures

Superconducting Quantum Circuit Research Group

Superconducting Quantum Circuits

Manipulating quantum states using superconducting devices

Ultimate Quantum Measurement and Sensing

Highly sensitive measurement technologies using quantum mechanical effects

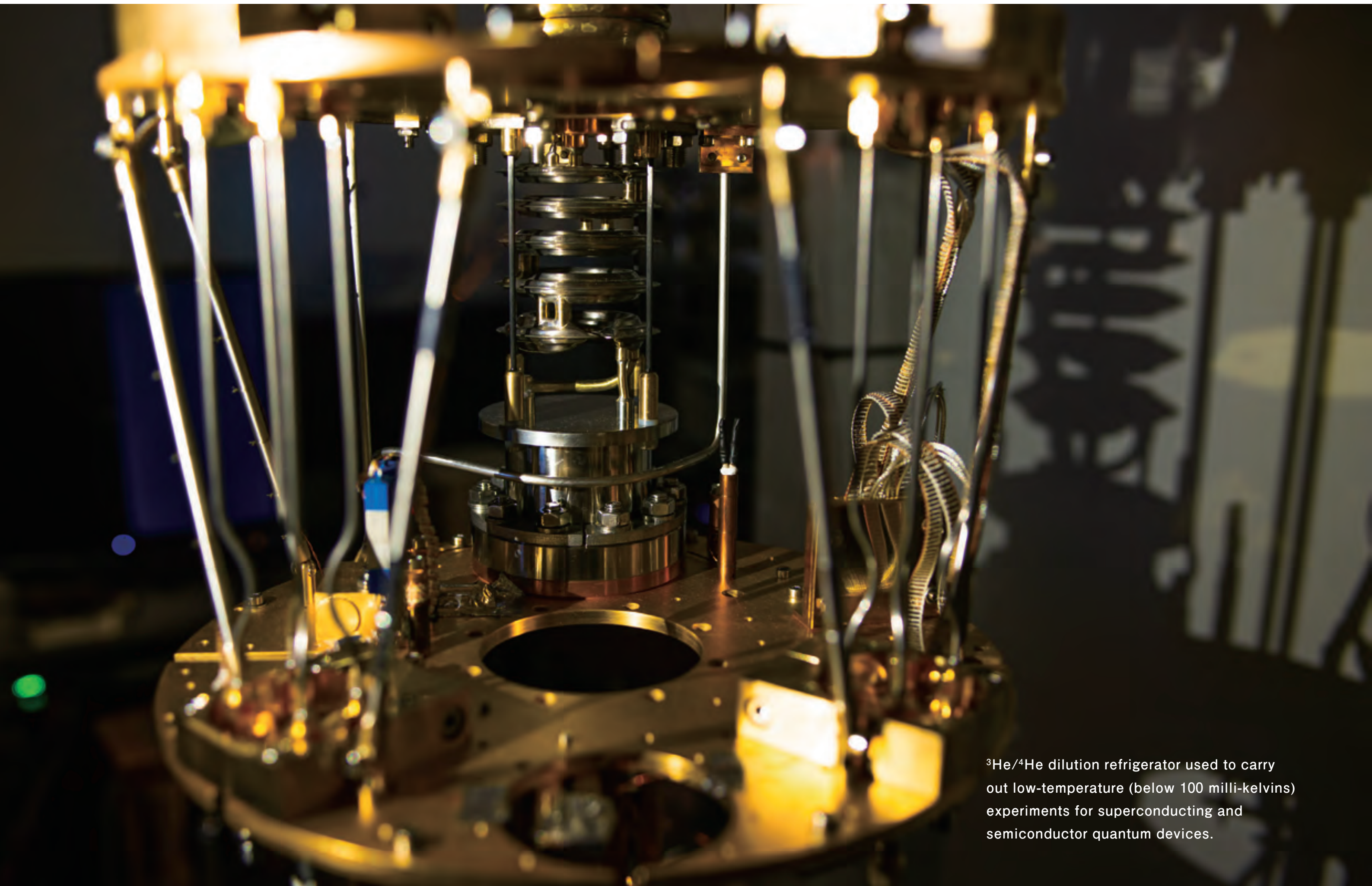
Quantum Solid State Physics Group

Quantum Transport in Hetero- and Nano-structures based on Semiconductor and 2D Materials

Unconventional charge and spin transport phenomena in quantum devices

Fast Coherent Carrier Dynamics in Electronic Devices

Information processing with coherent electron motion



$^{3}He/^{4}He$ dilution refrigerator used to carry out low-temperature (below 100 milli-kelvins) experiments for superconducting and semiconductor quantum devices.

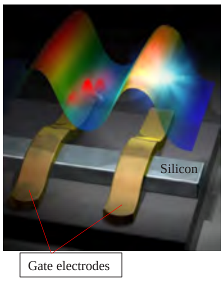
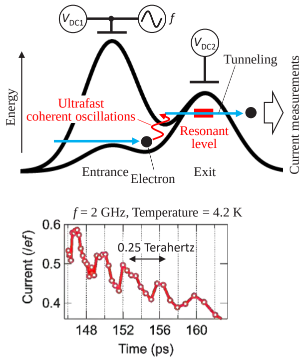


Image of the device and operation.

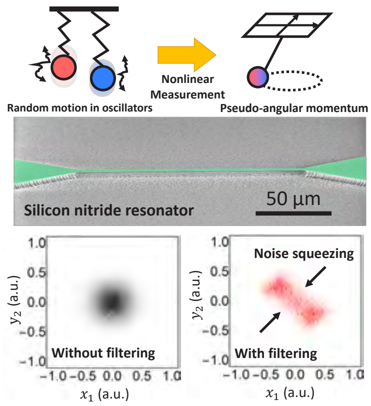


(Top) Electron potential diagram of the single-electron source.
(Bottom) Current oscillations originating from the coherent oscillations.

Measurements of Ultrafast Coherent Oscillations in a Silicon Single-electron Source

In a single-electron source that can periodically emit electrons one by one, we have succeeded in time-resolved detection of ultrafast quantum-mechanical coherent oscillations in the sub-terahertz regime, which are impossible to detect using existing measurement techniques. We detect them by temporally changing the energy of an oscillating electron and utilizing tunneling, which is allowed in a narrow energy band, through a resonant level. This is a new technique aiming for the observation of ultrafast quantum phenomena and could lead to a readout of ultrafast quantum bits.

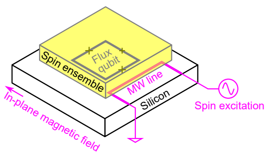
G. Yamahata, S. Ryu, N. Johnson, H.-S. Sim, A. Fujiwara, and M. Kataoka,
Nat. Nanotechnol. 14, 1019 (2019).

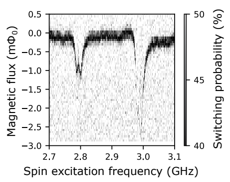


Mechanical Noise Squeezing Via Nonlinear Measurement

An important issue in sensing applications with a mechanical resonator is how to reduce mechanical noises to increase sensitivity. We proposed a scheme for noise squeezing and demonstrated it with a silicon-nitride resonator. So far, an external driving force has been required for noise squeezing. We succeeded in noise squeezing by directly observing a pseudo-angular momentum between mechanical modes via an optical nonlinear measurement and by filtering out its polarity. This result can be extended to novel technologies for controlling mechanical systems without an external driving field.

M. Asano, R. Ohta, T. Aihara, T. Tsuchizawa, H. Okamoto, and H. Yamaguchi, Phys. Rev. A 100, 053801 (2019).



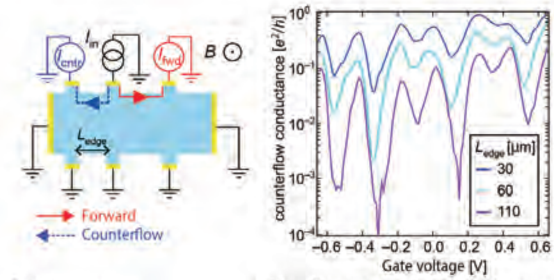


(Left) Electron spin resonance spectrometer using a superconducting flux qubit.
(Right) Electron spin resonance spectrum of nitrogen-vacancy centers in diamond.

Electron Spin Resonance Spectroscopy Using a Superconducting Flux Qubit

We developed an electron spin resonance spectrometer using a superconducting flux qubit with sensing volume of 50 fL and sensitivity of 400 spins/$\sqrt{\text{Hz}}$. This spectrometer can sweep the magnetic field and microwave frequency for the spectroscopy, making it possible to refine material parameters. The high spatial resolution also enables us to obtain the spatial distribution of electron spins in materials.

H. Toida, Y. Matsuzaki, K. Kakuyanagi, X. Zhu, W. J. Munro, H. Yamaguchi, and S. Saito,
Commun. Phys. 2, 33 (2019).



Experiment setup.
The counter flowing edge current is detected with an electrode at a distance of L_{edge}.

Gate voltage vs. counterflow conductance.
As the distance increases, the counterflow edge conductance decreases and approaches equilibrium state.

Clarification of Equilibration Process of Quantum Hall Edge Current

In the quantum Hall effect, which is used as an electrical resistance standard, a unidirectional edge current without backscattering flows along the edge of a sample due to the cyclotron motion under the influence of a repulsive potential at the edge. We investigated the quantum Hall effect in a sample with an attractive edge potential and detected counterflowing edge current. Furthermore, we have clarified the equilibration process in which the counterflowing edge current decays as the distance increases. Clarification of the edge state is important for realizing fault-tolerant quantum computing based on the quantum Hall effect.

T. Akiho, H. Irie, K. Onomitsu, and K. Muraki, Phys. Rev. B 99, 121303(R) (2019).

Optical Science Laboratory

Overview

The Optical Science Laboratory is pursuing the development of core technologies that will lead to innovations in optical communication and optical signal processing and to fundamental scientific progress. Central themes are quantum communication, physical computing with optical techniques, ultra-short light-matter physics pulse light, the optical frequency standard, and optical and spin properties in nanostructures.

Group Introduction

Quantum Optical State Control Research Group

Photonic Quantum Communication

Control of quantum state of light and its application to novel communication systems

Non-von Neumann Computation Using Quantum Optics

New computers based on coupled optical oscillators

Theoretical Quantum Physics Research Group

Theoretical Quantum Information Science

Proposal and systematic design of quantum computation, communication, network and metrology schemes including architectures.

Quantum Optical Physics Research Group

Manipulation of Ultrafast and Ultra-stable Laser Field

Explore ultrafast physics and establish the standard optical frequency

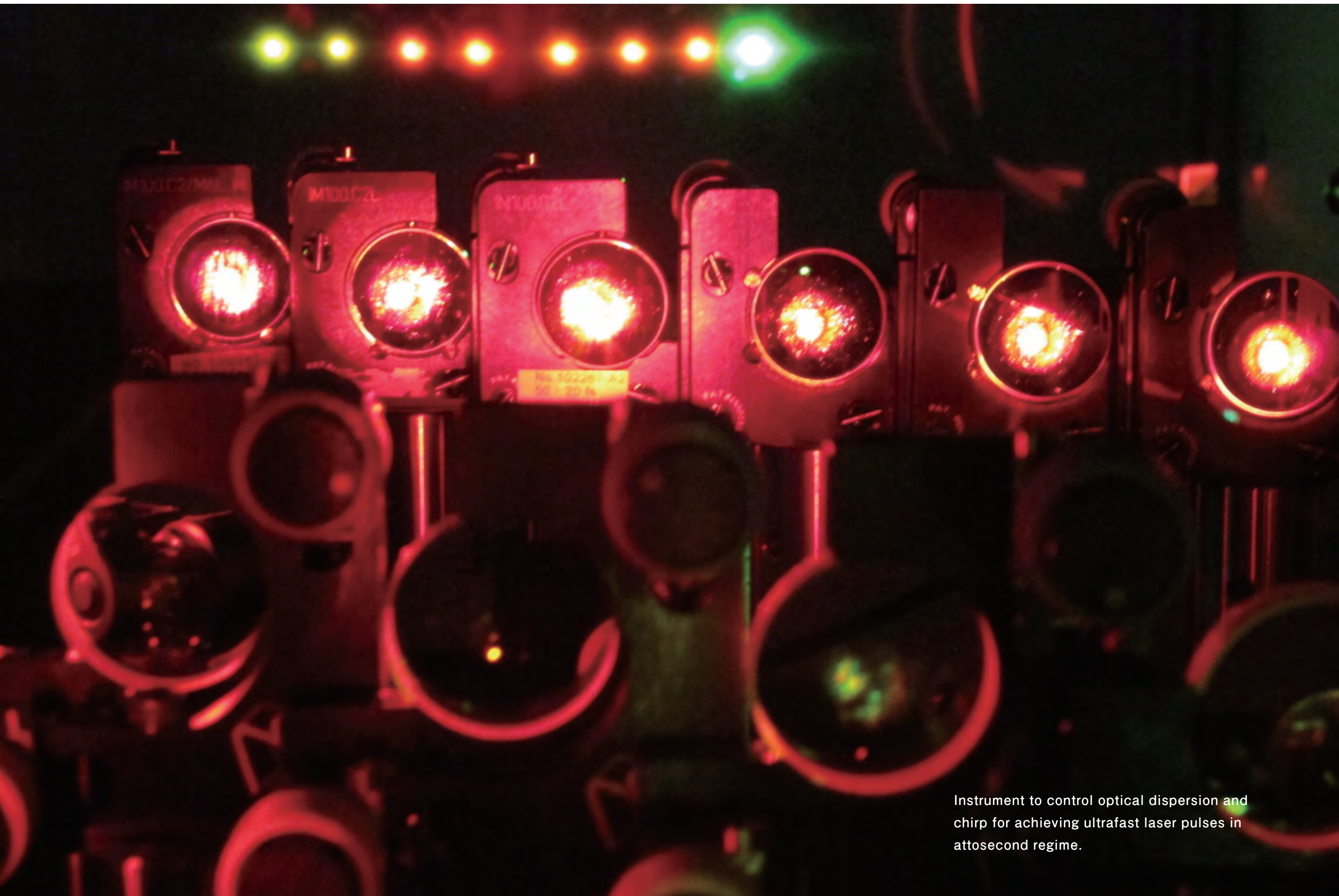
Nano-scale Physics in Optically-active Materials

Characterize photons, excitons and spins in the semiconductor nano-structures and rare-earth ions.

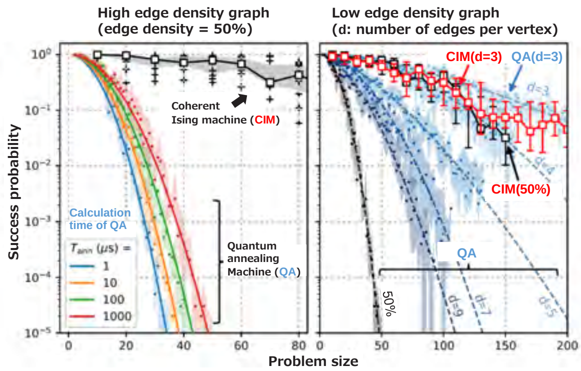
Photonic Nano-Structure Research Group

Integrated nanophotonics technologies

Ultra-compact and ultra-low power photonic devices and circuits, novel photonic phenomena in nanostructures



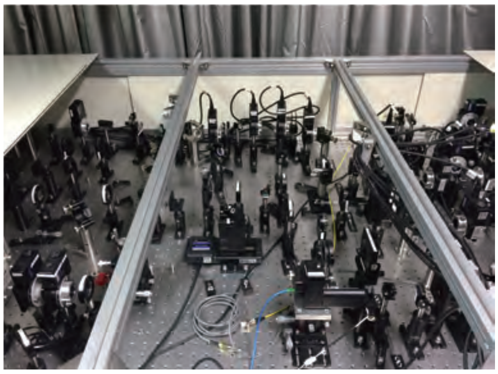
Instrument to control optical dispersion and chirp for achieving ultrafast laser pulses in attosecond regime.



Experimental Investigation of Performance Differences Between Coherent Ising Machines and a Quantum Annealer

We have developed a coherent Ising machine based on a network of degenerated optical parametric oscillators to solve combinatorial optimization problems. We performed a benchmark study in which we compared the CIM with a quantum annealing machine based on a network of superconducting qubits. An evaluation of the success probability of the ground state search problem for various graph instances confirmed that our CIM can solve high-edge-density graphs with success probabilities higher than those of the quantum annealing machine.

R. Hamerly, T. Inagaki, P. L. McMahon, D. Venturelli, A. Marandi, T. Onodera, E. Ng, C. Langrock, K. Inaba, T. Honjo, K. Enbutsu, T. Umeki, R. Kasahara, S. Utsunomiya, S. Kako, K. Kawarabayashi, R. L. Byer, M. M. Fejer, H. Mabuchi, D. Englund, E. Rieffel, H. Takesue, and Y. Yamamoto, Sci. Adv. 5, eaau0823 (2019).

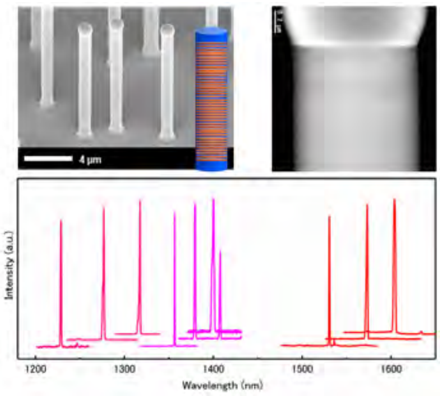


Experimental setup

First Proof-of-principle Experiment of All-photonic Quantum Repeaters

A quantum internet, enabled by quantum repeaters, is the Holy Grail of information-processing networks. It will have capabilities far exceeding those of the current Internet, such as quantum cryptography and quantum computation. In collaboration with Osaka University, the University of Toyama, and the University of Toronto, we have successfully conducted a proof-of-principle experiment for all-photonic quantum repeaters. This opens a path to an energy-efficient high-speed global 'all-optical' quantum internet.

Y. Hasegawa, R. Ikuta, N. Matsuda, K. Tamaki, H.-K. Lo, T. Yamamoto, K. Azuma, and N. Imoto, Nat. Commun. 10, 378 (2019).

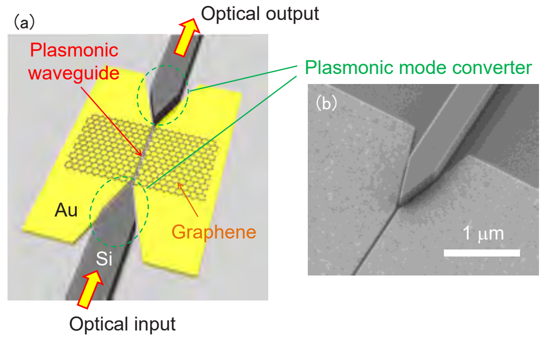


Electron microscopy images and lasing spectra

Telecom-band Nanowire Lasers

We have established a technology in which a bottom-up self-catalysed vapor-liquid-solid method is used to grow InP/InAs heterostructure semiconductor nanowires. When the the thickness of an InAs quantum disk is precisely modulated, the high-quality crystalline nanowire structure achieves lasing at room temperature in the whole telecom-band range of 1300–1600 nm. This technology is expected to produce a seamless connection between the direct formation of a coherent light source, which has been the biggest obstacle to developing optical-electronic integrated circuits, and an optical fiber communications network.

G. Zhang, M. Takiguchi, K. Tateno, T. Tawara, M. Notomi, and H. Gotoh, Sci. Adv. 5, eaat8896 (2019).



(a) Schematic of the graphene-loaded plasmonic waveguide.
(b) Scanning electron microscope image of the plasmonic mode converter.

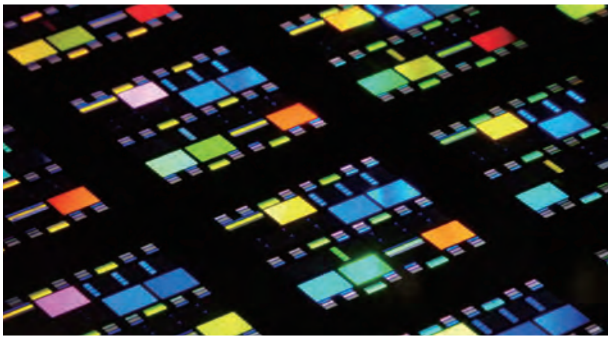
Ultrafast and Energy-efficient All-optical Switching

Previously reported all-optical switches would have difficulty operating at an ultrahigh speed with low energy consumption. We have demonstrated an ultrafast all-optical switching operation with the lowest energy consumption (35 fJ/bit) ever reported for all-optical switching at less than one picosecond. The current achievement combines a plasmonic waveguide with a core size of 30 nm × 20 nm with graphene, which has an ultrafast nonlinear optical response. Such ultrahigh switching speed cannot be achieved by electrical control. It is expected that this switch will be used in future photonic integrated circuits for ultrafast information processing.

M. Ono, M.Hata, M. Tsunekawa, K. Nozaki, H. Sumikura, H. Chiba, and M. Notomi, Nat. Photonics 14, 37 (2020).

Nanophotonics Center

Nanophotonics Center



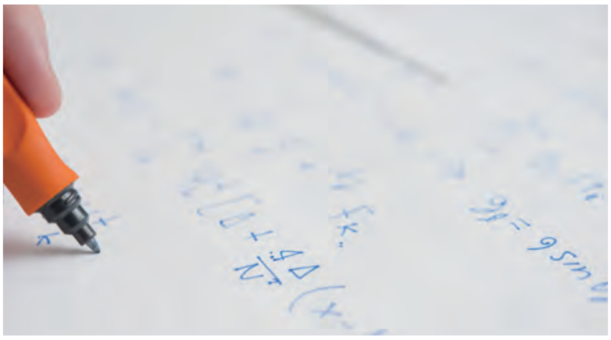
Overview

The Nanophotonics Center was established in April 2012 and is composed of several groups involved in nanophotonics research at NTT Basic Research Laboratories and NTT Device Technology Laboratories. We are conducting studies of photonic crystals to reduce the footprint and energy consumption of various photonic devices, such as optical switches, optical memories, modulators, lasers, and photo-detectors. We are also studying various photonic nanostructures to greatly enhance light-matter interactions, and exploiting photonic integrated circuits and devices for on-chip signal processing.

- **Extreme enhancement of light-matter interactions by using photonic crystals and plasmonics**
- **Integrable nanophotonic devices with extremely small energy consumption**
- **Nano-imprint, SPM lithography and manipulation**
- **Integration of various high-performance devices on a silicon platform**

Research Center for Theoretical Quantum Physics

Research Center for Theoretical Quantum Physics



Overview

The twentieth century saw the discovery of quantum mechanics, a set of principles that explains the nature of matter and light at the atomic level. These counter-intuitive principles have not only dramatically changed our understanding of the reality of our physical world but also enabled a technological revolution. They are responsible for the digital age in which we live. Naturally arising questions are what further can we learn from these principles and what technological advances could be enabled. The newly formed Center for Theoretical Quantum Physics established in July 2017 brings together diverse researchers (physicists, computer scientists, mathematicians and even chemists) from across NTT to pursue cutting edge research in a highly collaborative environment.

- **The foundation of quantum mechanics**
- **Quantum matter (hybrid quantum systems, strongly correlated systems, condensed matter and superconducting systems)**
- **Quantum algorithms and complexity**
- **Quantum communication, simulation and computation**
- **Quantum metrology and sensing**
- **Atomic, molecular and optical physics**

Bio-Medical Informatics Research Center

Bio-Medical Informatics Research Center

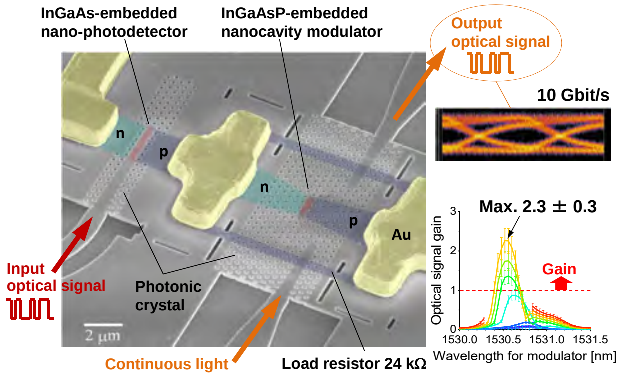
Overview

The Bio-Medical Informatics Research Center (BMC) was established in July, 2019 as a research organization in which five NTT laboratories collaborate with the goal of creating data-driven medicine using ICT. The BMC engages in basic and applied research on AI analyses of medical and health data, genome information and behavior information, real-time biomonitoring in daily life, biomimetic nanodevices, and new biocompatible materials. In addition, it promotes innovations in medical and health fields in cooperation with partners at medical institutes and Medical & Health Informatics Laboratories (MEI Lab), NTT Research, Inc.

- **Personalized medicine by AI analysis of personal medical data (precision medicine)**
- **Long-term Holter ECG measurement and rehabilitation activity supported by hitoe**
- **Lifestyle-related disease management based on noninvasive blood glucose sensing, core body temperature measurement, and AI risk analysis**
- **Fabrication of implant materials and artificial neural networks that complement biological functions**

Optical Transistor

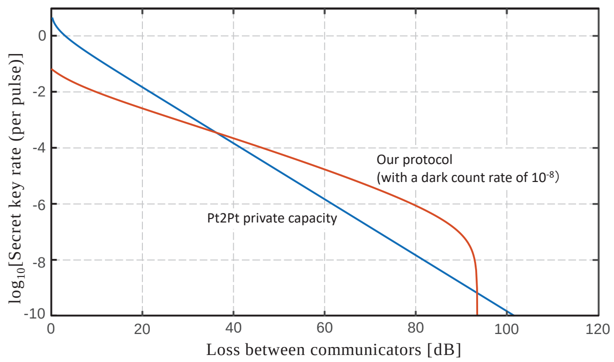
We used photonic-crystal nanostructures to fabricate an ultrasmall energy-saving photodetector (O-E converter) and optical modulator (E-O converter). By closely integrating these two converters, we succeeded in operating an optical transistor (O-E-O converter), which can transfer optical signal data to another light with signal gain. The capacitance of the device is remarkably suppressed down to only 2 fF, which results in an operating energy that is two-orders of magnitude smaller than those for existing technologies. Such a nanophotonic device will serve as a fundamental component for high-speed opto-electronic signal processing chip.



K. Nozaki, S. Matsuo, T. Fujii, K. Takeda, A. Shinya, E. Kuramochi, and M. Notomi, Nat. Photonics 13, 454 (2019).

Quantum Key Distribution Enabling 500-km Cryptographic Communication and its Security

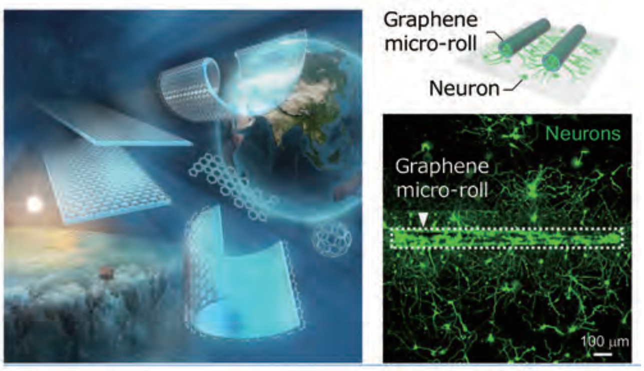
Quantum key distribution (QKD) presents secure communication against arbitrary eavesdropping, including attacks based on quantum computers. Recently, twin-field QKD was proposed as a scheme to surpass the private capacity of a point-to-point (Pt2Pt) optical fiber link by using a repeater node between communicators. However, its security was merely a conjecture. In collaboration with the University of Vigo and the University of Toronto, we have proposed a simpler twin-field QKD scheme and proved its security. Our scheme exceeds the point-to-point private capacity, opening up the possibility of quantum cryptography within a radius of 500 km.



M. Curty, K. Azuma, and H.-K. Lo, npj Quantum Inform. 5, 64 (2019).

Reconstitution of a Neural Network Using a Thin-film-based 3D Template

We demonstrated that graphene, a carbon-based nanomaterial, spontaneously assembles into a three-dimensional structure when transferred onto a polymeric thin film. The assembled 3D structure was used as a cell scaffold on which neurons were successfully cultured and reconstituted into functional neuronal tissue. The reconstituted neuronal tissues were found to exhibit cell-cell interactions by forming a network in which they were connected to external neurons. Owing to the excellent conductivity of graphene, the technology developed in this study can be applied to not only new tools for cell biology and tissue engineering but to biocompatible and implantable bioelectrodes as well.



T. F. Teshima, C. S. Henderson, M. Takamura, Y. Ogawa, S. Wang , Y. Kashimura, S. Sasaki, T. Goto, H. Nakashima, and Y. Ueno, Nano Lett. 19, 461 (2019).
K. Sakai, T. F. Teshima, H. Nakashima, and Y. Ueno, Nanoscale 11, 13249 (2019).

NTT Fellow

The title of "NTT Fellow" is reserved for our most gifted scientist and engineers whose research and development activities have brought them significant distinction both within NTT and internationally. Our "Fellows" are extremely highly regarded. Next the title of "Senior Distinguished Researcher" is given to outstanding individuals who have established themselves as global intellectual leaders of their own research areas. The "Distinguished Researcher" title is given to innovative researchers whose impressive achievement has been recognized both within and outside NTT.
They all are responsible for leading innovative research and cutting-edge technical developments in research areas considered important to NTT.

December 31, 2019

Medicine, Physiology, Biomedical interface & data analysis

Shingo Tsukada

Research Subject

Biological Information Elucidation Using Advanced Medical Materials

Senior Distinguished Researcher

Nanophotonics Center Project Manager

Masaya Notomi

Research Subject

Photon Manipulation in Photonic Nanostructures

Quantum and Nano Device Research

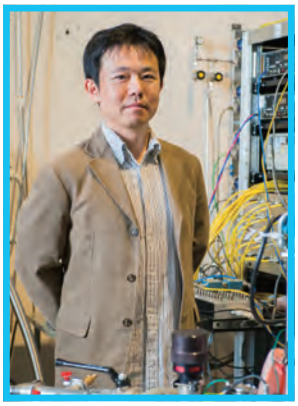
Hiroshi Yamaguchi

Research Subject

Nano-mechanics in Semiconductors

Quantum Solid State Physics Research Group Leader

Koji Muraki

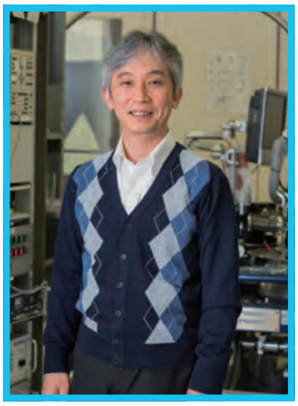


Research Subject

Electron Correlation in Semiconductor Nanostructures

Physical Science Laboratory Executive Manager

Akira Fujiwara

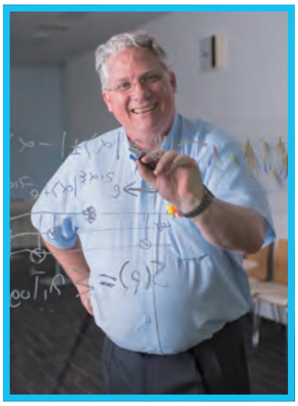


Research Subject

Ultimate Electronics Using Semiconductor Nanostructures

Research Center for Theoretical Quantum Physics Project Manager

William John Munro



Research Subject

The Design of Quantum Technologies

Quantum Optical State Control Research Group Leader

Hiroki Takesue

Research Subject

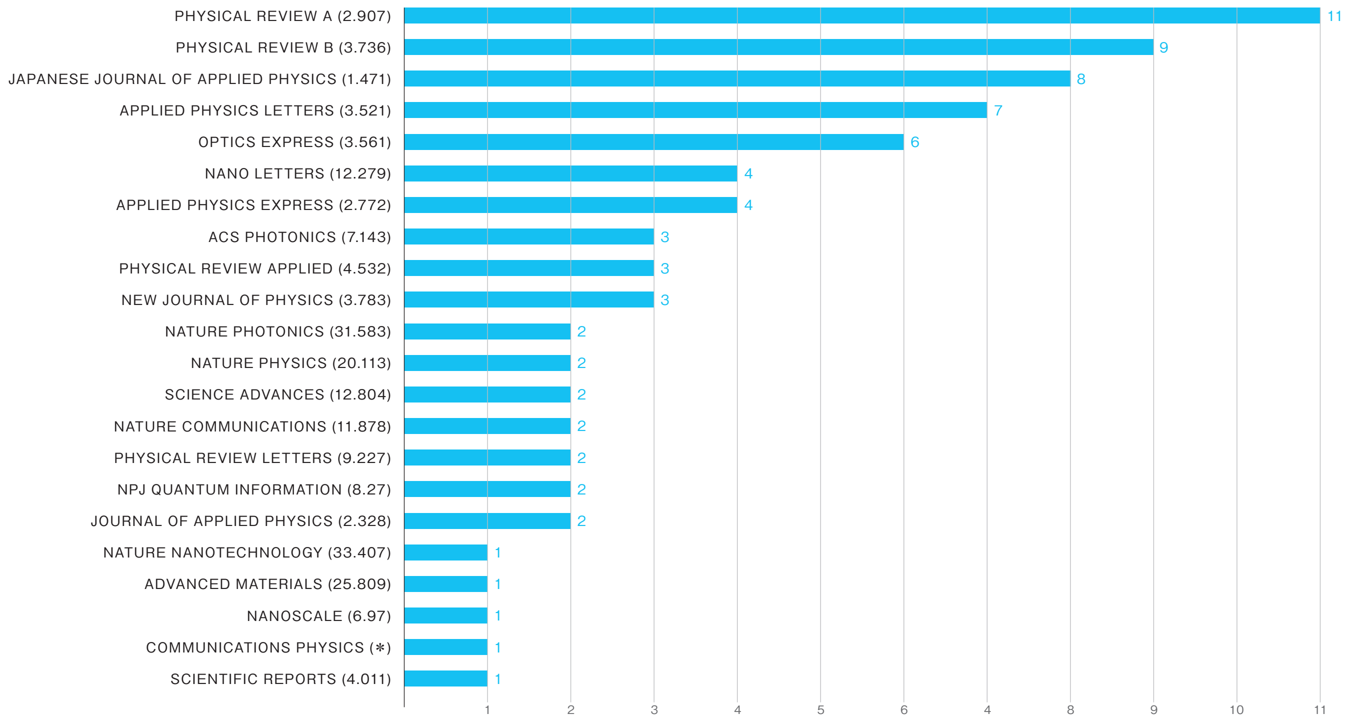
Quantum Communication Experiments in Telecommunication Band
Coherent Ising Machine

Distinguished Researcher

Norio Kumada, Shiro Saito, Haruki Sanada, Kengo Nozaki, Hiroki Mashiko
Katsuhiko Nishiguchi, Imran Mahboob, Koji Azuma, Yuko Ueno, Takahiro Inagaki

Publication List

( )…The average IF2018 for all research papers from NTT Basic Research Laboratories is 5.689
*…IF has not counted because the journal started 2018.
The number of papers published in international journals in 2019 is 103.



Number of Presentations

222
(54 Invited talks)

Number of Patents

77

List of Award Winners

JSPS PRIZE
Research on Wide Bandgap Semiconductor Ultraviolet Light-Emitting Devices **Yoshitaka Taniyasu**

The Young Scientists' Prize, the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology
Extremely-power-saving optical devices based on semiconductor photonic crystal **Kengo Nozaki**

IEICE Technical Committee on Reconfigurable Systems
Design and implementation of FPGA measurement feedback system inCoherent Ising Machine **Toshimori Honjo**

Achievement award in the laser society of Japan
Precision frequency conversion using an electo-optics-modulation comb **Atsushi Ishizawa, Tadashi Nishikawa, Kenichi Hitachi, Hideki Gotoh**

JSAC Female Analyst Award
Creation of molecular recognition functional materials and its application to micro analysis **Yuko Ueno**

IOP Publishing Outstanding Reviewer Award 2018
Outstanding Reviewer for Semiconductor Science and Technology in 2018 **Xuejun Xu**

Certificate of Award for Encouragement of Research in the 29th Annual Meeting of MRS-J Symposium L
Creation of Tough Hydrogel Architectures Towards Obtaining Hydrogel Fluidic Devices **Riku Takahashi**

JSAP Young Scientist Presentation Award
Radiative lifetime of bound excitons in GaAs with vibrational strain **Ryuichi Ohta**

JSAP Young Scientist Presentation Award
Jeff=3/2 ferromagnetic insulating state above 1000 K in a double perovskite osmate synthesized by molecular beam epitaxy **Yuki Wakabayashi**

JSAP Young Scientist Presentation Award
Directed aggregation of cardiomyocytes by topographical guides in co-culture system **Hiroki Miyazako**

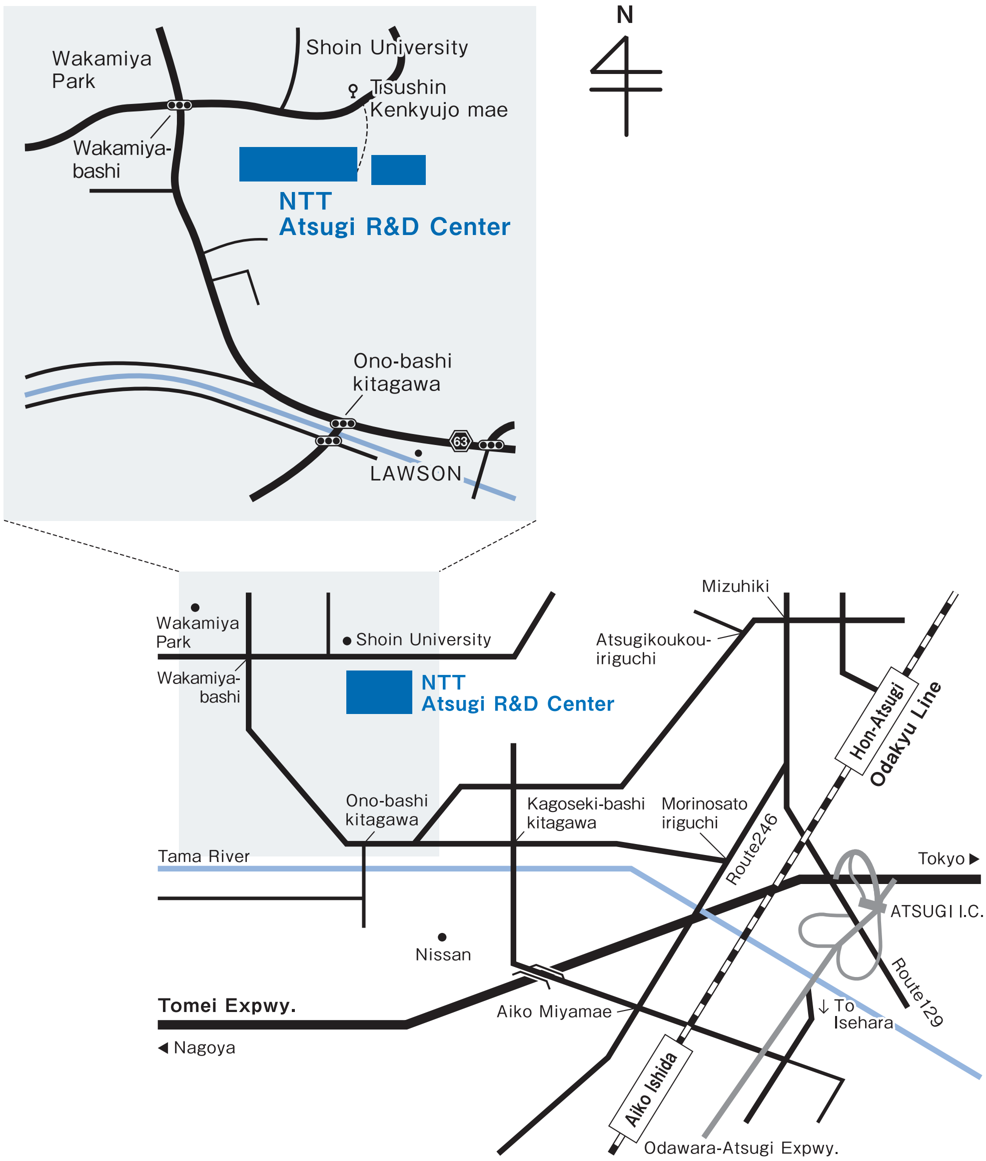
NTT

NTT Basic Research Laboratories

3-1, Morinosato Wakamiya, Atsugi, Kanagawa, 243-0198 Japan

TEL +81-46-240-3312 MAIL brl-info@hco.ntt.co.jp

http://www.brl.ntt.co.jp/



Access

By train and bus

"Aiko-Ishida" station on Odakyu Line (1 hour from Shinjuku by express)
North Exit Bus Depot 4
20 minutes bus ride on "愛17, 愛19 Morinosato" route; get off at "Tsushin Kenkyujo-mae" bus stop.
20 minutes bus ride on "愛18, 愛21 Shoin Daigaku" route; get off at "Tsushin Kenkyujo-mae" bus stop.

"Hon-Atsugi" station on Odakyu Line (1 hour from Shinjuku by express)
East Exit Bus Center Pole 9
30 minutes bus ride on "厚44 Morinosato via Akabane/Takamatsuyama" or
"厚45 Morinosato via Funako/Morinosato-Aoyama" get off at "Tsushin Kenkyujo-mae" bus stop.

By taxi

15 minutes from "Aiko-Ishida" station on Odakyu Line (around 1,500yen) or 20 minutes from "Hon-Atsugi" station on Odakyu Line (around 2,500yen)

By car

20 minutes (5km) drive from Tomei Expwy "Atsugi I.C."; get off the Expwy toward Isehara and turn right at the Taya crossroads.