NTT Basic Research Laboratories

Annual Report 2024

NTT BASIC RESEARCH LABORATORIES

Greetings

NTTBRL's Annual Report 2024 is now available.
We are pleased to be able to present our basic research activities to all of you, and we are grateful for your continued warm support.
On behalf of NTT Basic Research Laboratories, I would like to express our sincere gratitude to you.

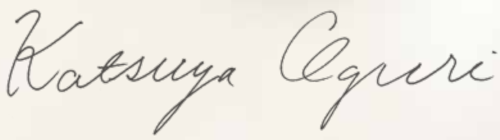
NTT Basic Research Laboratories (NTT-BRL) was established at the same time as the privatization of NTT in 1985. The original mission statement of NTT-BRL was to "create world-class new knowledge and concepts that will induce academic development and innovation in the fields of telecommunications and information communications, and as a result, provide the seeds for next-generation technologies to all NTT R&D".
During the 40 years since NTT-BRL's establishment, telecommunications and information communications technologies have advanced dramatically and penetrated deeply into our society. These technologies have created contact points with a wide range of fields such as energy, computing, security, sensing, materials, bio-medical, and artificial intelligence. Their importance to society has never been greater.

At NTT-BRL, professionals from a wide range of fields, including physics, chemistry, engineering, biology, mathematics, information-science, and medicine, are working on cutting-edge research in materials science, solid-state and optical science, and quantum science, and are continually challenging the limits of technology and knowledge. To this end, NTT-BRL conducts a wide range of joint research with universities and research institutes all over the world. This "open door policy" is an important part of NTT-BRL's activities for building up our community of basic research.

As a highlight of 2024, we have made significant progress in our research on topological properties manifested in photonic and phononic nanostructures, high-order harmonic topological beam generation based on the symmetry of materials and nonperturbative nonlinear interactions, and ultrashort terahertz plasmon wave generation on graphene, a material composed of one layer of carbon atoms. These surprising demonstrations illustrate the future technological potential of solid-state physics. We also held locally the international school and symposium on nanodevices and quantum technologies 2024 (ISNTT2024) for the first time in five years. This event is an important opportunity for researchers and students from all over the world to meet together, interact, and develop friendships at the Atsugi R&D Center.

"We will create a deeper understanding of nature, expand its possibilities, and create a compass for a better world."
This is the spirit of NTT-BRL that I set forth when I took over from former Director Kazuhide Kumakura in October 2024. We at NTT-BRL have never forgotten our origins and are always looking to the future of the world.

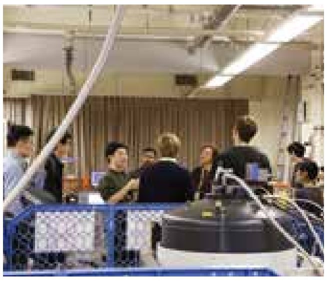
Your continued support would be highly appreciated.



Dr. Katsuya Oguri
Vice President, Head of NTT Basic Research Laboratories

ISNTT

We hosted the international symposium “ISNTT 2024” (International School and Symposium on Nanodevices and quanTum Technologies), focusing on quantum information technology and semiconductor and superconductor quantum physics. The symposium featured a keynote lecture by Professor Richard Jozsa from the University of Cambridge, 17 invited talks, 35 general oral presentations, and 123 poster presentations. A total of 263 attendees, the largest number in ISNTT’s history, engaged in lively discussions on the latest research findings in related fields.



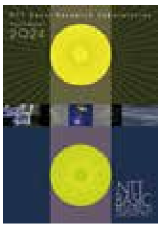
BRL School

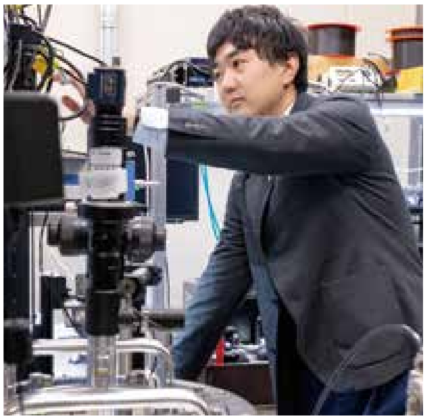
In order to raise awareness of the NTT Basic Research Laboratories and provide opportunities for young researchers to grow in their field of study, we have hosted the 'NTT-BRL School,' primarily aimed at doctoral students. However, during the COVID-19 pandemic, the school had to be suspended. This year, we resumed the school after a hiatus of five years, with 'Quantum Information' as the theme. A series of lectures was delivered by speakers from various organizations, Professor Marcus Curty (University of Vigo), Professor William J. Munro (OIST), and Professor Keisuke Fujii (Osaka University), as well as from BRL, Dr. Koji Azuma (Project manager of the TQC and Leader of the Theoretical Quantum Physics Research Group). In addition to attending lectures and lab tours, the participants presented their own research at the concurrently held ISNTT.

Front image:

In-liquid optomechanics

By using an optical cavity that can confine light within a small region, it is possible to detect and control thermal fluctuations that cause an object to vibrate slightly at ambient temperature. If this technique can be applied to liquids, liquid surfaces, and soft matter, it will lead to the creation of extremely sensitive sensors for chemical and biological investigations. NTT Basic Research Laboratories has fabricated a new sensor element that combines an optical cavity and a mechanical resonator using a glass fiber as thin as a hair and has realized an ultra-sensitive vibration measurement technology in liquid and on liquid surfaces that uses this element. We succeeded in capturing the slight expansion and contraction of the fiber in the liquid with extremely high sensitivity with our unique method in which a resonator that confines light in the atmosphere is partially inserted into the liquid. In the future, we will establish technologies for measuring and controlling extremely small vibrations by using light and explore novel physical phenomena arising from the interweaving of mechanical vibrations in liquids, soft matter, and even biological systems.





Motoki Asano
Engaged in research on optomechanics using glass fiber devices

Organization

Vice President, Head of
NTT Basic Research Laboratories

Katsuya Oguri

Research Planning Section

Executive Manager
Masumi Yamaguchi

Multidisciplinary Materials Design and Science Laboratory

Executive Manager
Masumi Yamaguchi

→ P5

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

Advanced Applied Physical Science Laboratory

Executive Manager
Katsuya Oguri

→ P7

- Nanodevices Research Group
- Nanomechanics Research Group
- Quantum Optical Physics Research Group
- Photonic Nano-Structure Research Group

Quantum Science and Technology Laboratory

Executive Manager
Hiroki Takesue

→ P9

- Quantum Optical State Control Research Group
- Theoretical Quantum Physics Research Group
- Superconducting Quantum Circuits Research Group
- Quantum Solid State Physics Research Group

The population data of NTT-BRL members

- Researchers (Foreign Researchers)…97 (7)
- Postdoc/Research Specialist…6*
- Joint-Researchers…17*
- Domestic Interns…9*
- International Interns…21*
- Invited Professor…1*
- Guest Researchers…2*
- TQC Visitors…15*

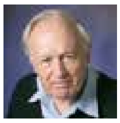
*…Jan-Dec 2024 total

As of Dec. 31, 2024

Advisory Board

Chalmers University of Technology, Sweden
Prof. Per Delsing

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



University of Illinois at Urbana-Champaign,USA
Prof. Sir Anthony J. Leggett

Imperial College,UK
Prof. Sir Peter Knight

Université Pierre et Marie Curie,France
Prof. Elisabeth Giacobino

The University of Texas at Austin,USA
Prof. Allan MacDonald

Forschungszentrum Jülich, Germany
Prof. Andreas Offenhäusser

CEA Saclay, France
Prof. Christian Glattli

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

Nanophotonics Center (NPC)

Project Manager
Masaya Notomi

P11

Research Center for Theoretical Quantum Information (TQC)

Project Manager
Koji Azuma

P11

Bio-Medical Informatics Research Center (BMC)

Project Manager
Katsuyoshi Hayashi

P11

Research Professors

Sakakibara Heart Institute, Advisor
Prof. Hitonobu Tomoike

Tohoku University
Prof. Masao Morita

University of Toyama
Prof. Kiyoshi Tamaki

Tohoku University, Professor Emeritus
Prof. Junsaku Nitta

Hiroshima University
Prof. Hideki Gotoh

Multidisciplinary Materials Design and Science Laboratory

Overview

The aim of the Multidisciplinary Materials Design and Science Laboratory is to contribute to progress in materials science and to revolutionize information communication technology by creating novel materials with various internal degrees of freedom (lattice, charge, spin, orbital, etc.) through materials design and synthesis beyond conventional concepts of classifications, dimensions, scales, and synthesis methods. The research groups that constitute this laboratory are investigating a wide range of materials including semiconductors, superconductors, magnetic materials, topological materials, conductive polymers, and biological soft materials. We are conducting innovative materials research based on advanced thin-film growth technologies, high-precision and high-resolution measurements of structures, properties along with theoretical studies, and data science (informatics).

Groups and Research Themes

Thin-Film Materials Research Group

Novel Semiconductor Devices

Creation of light-emitting devices over a wide range from DUV to NIR, high-efficiency energy conversion devices, high-power 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

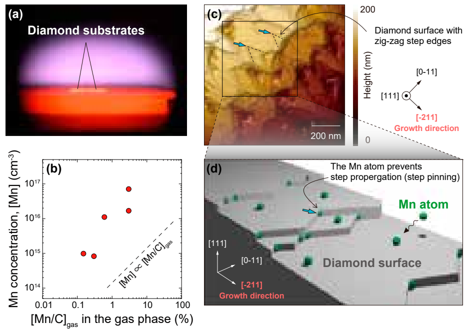
Biocompatible Electrode Materials

Development and application of bioelectrode materials for measurement of deep biological information

Bio-devices

Creation of bio-functional mimetic devices exploiting biomolecules, cells, and soft materials

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.

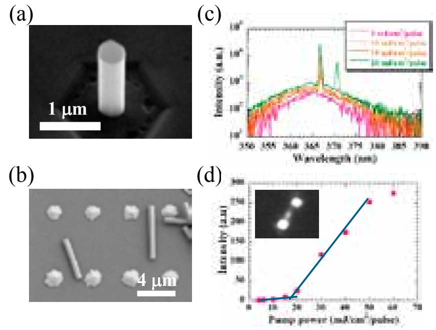


(a) Photograph taken during diamond growth by microwave plasma CVD.
(b) Mn concentration in diamond as a function of [Mn/C] ratio in the gas phase.
(c) AFM image of Mn-doped diamond (111) surface.
(d) Schematic growth mechanism of Mn-doped diamond (111) layer.

Growth Mechanism of Mn-doped Diamond (111) Layers

Impurity doping of diamond is an essential technique for adding new functionalities to it, including high-temperature ferromagnetism and high-brightness color centers. In this work, we demonstrated homoepitaxial growth of Mn-doped diamond (111) layers and control of the Mn concentration in them by using our custom-built microwave plasma CVD system. In addition, we clarified that the zig-zag step edges on the Mn-doped diamond surface originate from step pinning by Mn atoms absorbed on the surface. These findings will open up new spintronic and quantum-information device applications to diamond.

M. Kawano, K. Hirama, Y. Taniyasu, and K. Kumakura, Journal of Applied Physics 135, 075302 (2024).

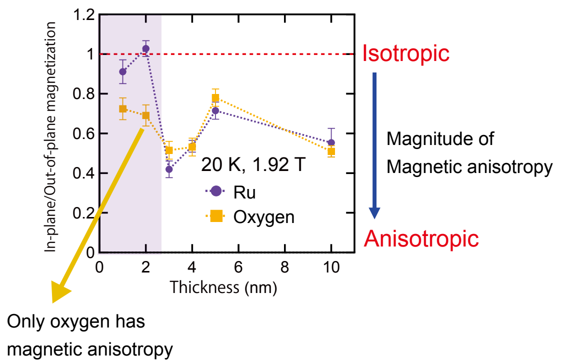


(a) Bird's eye-view scanning electron microscope image of nanowires after etching.
(b) Nanowires dispersed on a sapphire substrate.
(c) Photoluminescence spectra from a single nanowire at various pump powers.
(d) Emission intensity as a function of excitation intensity. Strong emission from the end facets of the nanowire can be seen in the inset image.

Fabrication of Nitride Semiconductor Nanowires

Nanophotonic devices made from nitride semiconductors, which can emit light in the near-infrared to ultraviolet range, are expected to offer low power consumption, high-speed operation, and compact integration. In this study, we established a top-down fabrication technique for nanowires with an AlGaInN light-emitting diode structure by refining the etching method and confirmed laser oscillation (around 365 nm) through optical excitation measurements of the nanowires. Moving forward, we will fabricate nanowires with a higher Al composition aiming for an emission wavelength of 220 nm, and integrate them into photonic devices.

K. Tateno, M. Takiguchi, K. Ebata, S. Sasaki, K. Kumakura and Y. Taniyasu, Phys. Status Solidi A 221, 2400078 (2024).

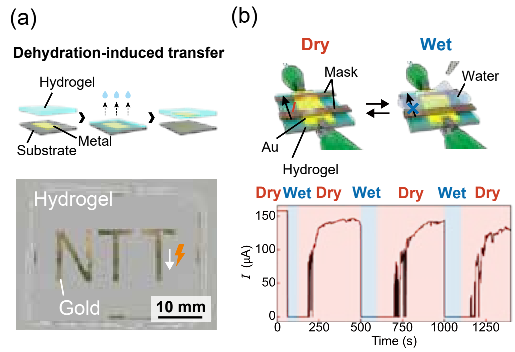


Thickness dependence of $SrRuO_3$ thin films on the magnitude of Ru and oxygen magnetization in the in-plane direction compared to the out-of-plane direction.

Magnetic Anisotropy Driven by Ligand in 4d Ferromagnetic Metal $SrRuO_3$

The origin of magnetic anisotropy in magnets has been a longstanding mystery in solid-state physics, and it has generally been believed that nonmagnetic ligand ions do not contribute to it in magnetic compounds. To unravel this mystery, we investigated the magnetic anisotropy of Ru and the nonmagnetic element oxygen (ligand) in ferromagnetic metal $SrRuO_3$ thin films at the synchrotron radiation facility SPring-8. For thin films with a thickness of 1–2 nm, it was found that while the magnetic moment of Ru is isotropic, only the magnetic moment of oxygen exhibits anisotropy. This revealed that the anisotropy of oxygen is the origin of the magnetic anisotropy.

Y. K. Wakabayashi et al., APL Mater. 12, 041119 (2024); J. Appl. Phys. 136, 043907 (2024).



(a) Adhesion to metal films can be achieved with arbitrary shapes.
(b) The metal transferred onto a fully dehydrated hydrogel becomes electrical wiring that changes conductivity as the gel swells and shrinks in response to ambient moisture.

Dehydration-induced Adhesion Method for Facile Integration of Hydrogel and Metal Films

Soft, wet hydrogels and hard, dry metals are difficult to adhere because of their different properties. In this study, we found a facile adhesion method in which a hydrogel film is placed on a metal thin film formed on a substrate, and the metal is transferred from the substrate by inducing a hydrophobic interaction between the gel and the metal during the dehydration process of the hydrogel. Since the adhered metal wiring showed good conductivity even after re-swelling, this method is expected to become an important fabrication technology for hydrogel applications in electronics.

S. Himori, R. Takahashi, A. Tanaka, and M. Yamaguchi, ACS Omega, 9 (41) 42261-42266 (2024).

Advanced Applied Physical Science Laboratory

Overview

The Advanced Applied Physical Science Laboratory has launched towards the creation of innovative information communication technologies and future functional devices that bring long-term value for the accelerating technology-driven society. Leading research groups in the fields of nanoelectronics, nanomechanics, nanophotonics, spintronics, and quantum electronics are closely collaborating for this exciting challenge. We will pioneer the forefront of the applied physical science field and discover novel functionalities in solid-state quantum systems based on our nanofabrication technology, advanced measurement technology, and light-wave technology.

Groups and Research Themes

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

Opto/Electro/Magno-Mechanics

Searching and extracting new phenomena and functions that appear in microstructures with mechanical freedom

Phonon Manipulation

Controlling ultrasonic propagation using artificial acoustic crystals

Quantum Optical Physics Research Group

Manipulation of Ultrafast and Ultra-stable Laser Field

Ultrafast physics investigated by attosecond spectroscopy, Optical-lattice clock network

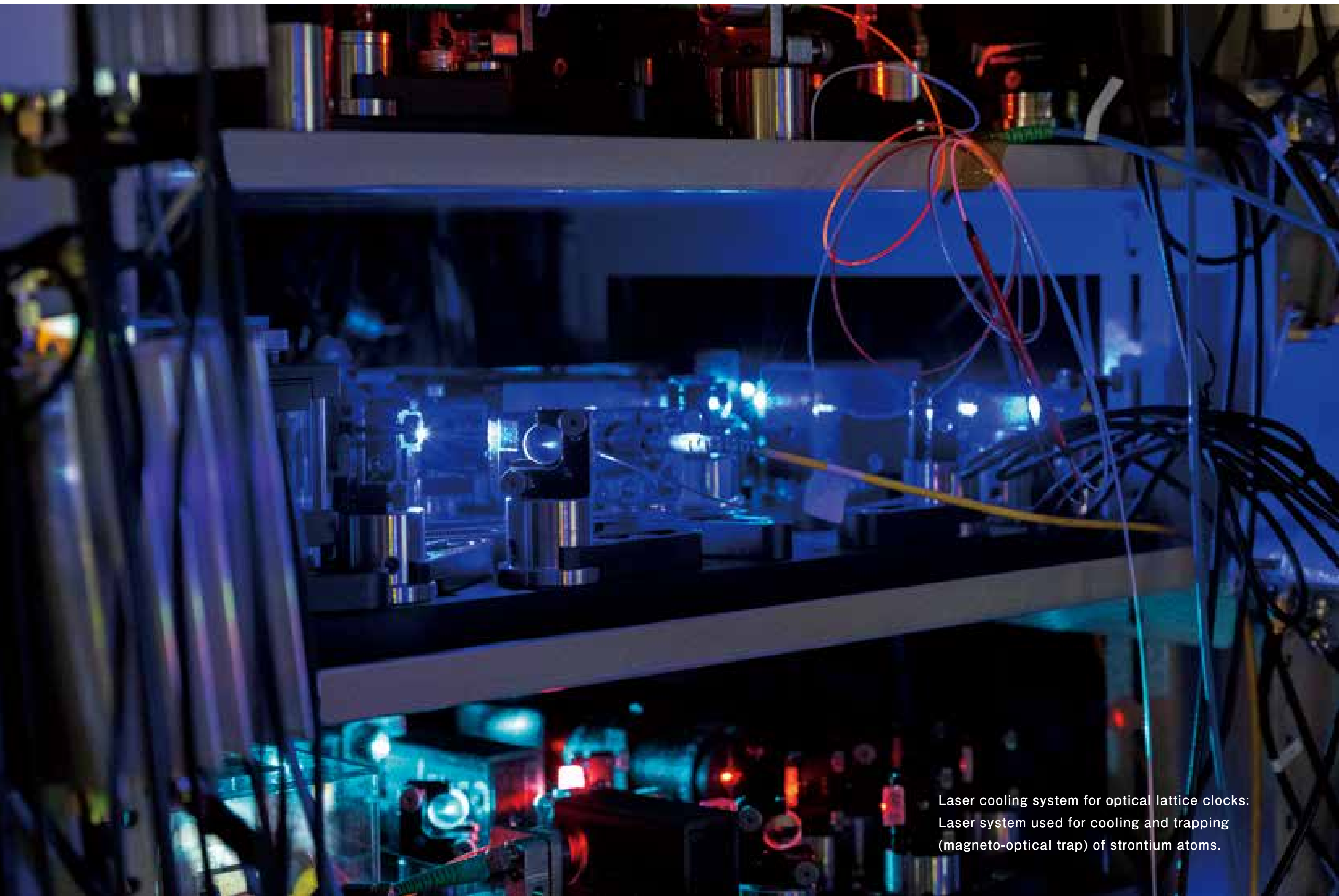
Nano-scale Physics in Optically-active Materials

Physics related to photons, excitons, and spins, in semiconductor nanostructures and rare-earth oxides

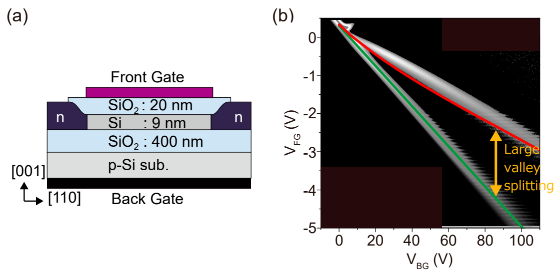
Photonic Nano-Structure Research Group

Integrated Nanophotonics Technologies

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



Laser cooling system for optical lattice clocks: Laser system used for cooling and trapping (magneto-optical trap) of strontium atoms.

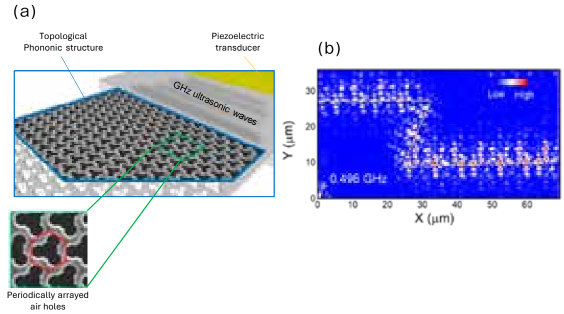


(a) Schematic diagram of the device.
(b) Comparison of experimental results of the valley splitting observed in the current of the device and the calculation (solid line) using a model incorporating strain.

Large Valley Splitting due to Strain

The degeneracy of valley states peculiar to silicon has become a problem affecting progress on silicon quantum computers. One of the most promising solutions to this problem is to utilize the large valley splitting observed at the Si/SiO2 interface, but the principle of this splitting has not yet been elucidated. Here, we focused on the fact that the valley degeneracy can be lifted by straining the silicon and thereby breaking the spatial symmetry and theoretically verified whether the large valley splitting can be reproduced. As a result, we found that the large valley splitting observed in the experiment can be well reproduced by a model that incorporates strain. This achievement serves as guidance for avoiding fundamental problems in silicon quantum computers.

J. Noborisaka, T. Hayashi, A. Fujiwara, and K. Nishiguchi, J. Appl. Phys. 135. 204302 (2024).

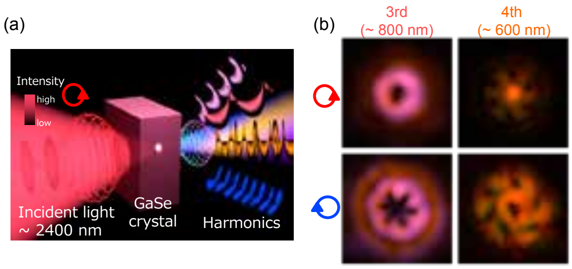


(a) Schematic diagram and SEM image of a GHz topological phononic structure.
(b) Robust propagation of GHz ultrasonic waves in a "Z"-shaped topological edge channel.

Robust Transport of GHz Ultrasonic Waves in Chip-scale Topological Phonon Structures

Wave propagation along boundaries or edges, protected by topological order, is theoretically expected to be robust against scattering from structural defects. However, it is not obvious whether this property is maintained in tiny nano/micrometer-scale structures. In this study, we investigated topological physics in such tiny structures by creating fine structures with artificial elastic crystals and demonstrated that GHz ultrasound can propagate robustly without being affected by structural defects.

D. Hatanaka, H. Takeshita, M. Kataoka, H. Okamoto, K. Tsuruta, and H. Yamaguchi, Nano Lett., 18, 5570-5577 (2024).

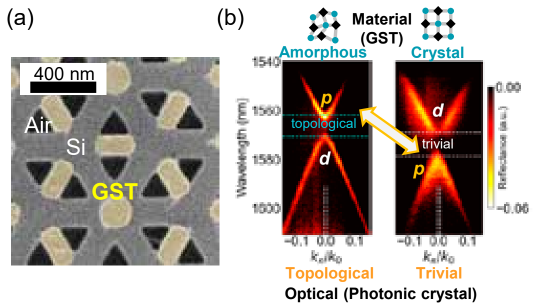


(a) Schematic diagram of high-harmonic generation in a crystalline solid.
(b) Beam profiles of third- and fourth-order harmonics of the left and right circularly polarized components.

Controlling the Polarization and Beam Profile in High-order Harmonic Generation by using the Symmetry of Crystalline Solids

High-order harmonic generation (HHG) is a process in which the wavelength of light is changed by passing an intense laser beam through a medium. In particular, this process generates short-wavelength light in the extreme ultraviolet range, which is difficult to achieve by other methods. By using solid crystals as a medium for HHG, we successfully controlled the polarization and beam profile of the harmonics by exploiting the symmetry properties of the crystals. In addition, we clarified the conversion rules for the polarization and beam profile associated with wavelength conversion. These findings will lead to new applications in microscopic imaging and laser processing that exploit the short-wavelength properties of the harmonics.

K. Nagai, T. Okamoto, Y. Shinohara, H. Sanada, and K. Oguri, Sci. Adv. 10, eado7315 (2024).



(a) SEM image of the fabricated topological photonic crystal. Nanometer-sized GST blocks are precisely deposited on the silicon photonic crystal.
(b) Photonic band structure measured by angle-resolved reflection spectroscopy. The intensity changes in the upper and lower bands indicate a photonic topological phase transition induced by the material phase transition.

Photonic Topological Phase Transition Induced by Material Phase Transition

Photonic topological structures with a high robustness against optical bending and structural disorders are attracting attention for application to photonic integrated circuits. However, photonic topological structures face challenges in terms of modifying their properties after fabrication. In this study, we controlled the topological properties of a hybrid silicon photonic crystal structure after fabrication, which was enabled by the deposition of the phase-change material $Ge_2Sb_2Te_5$ (GST). This achievement will lead to the development of novel functionalities that would be difficult to realize with silicon alone and expands the potential applications of photonic topological devices.

T. Uemura, Y. Moritake, T. Yoda, H. Chiba, Y. Tanaka, M. Ono, E. Kuramochi, and M. Notomi, Sci. Adv. 10 (34), eadp7779 (2024).

Quantum Science and Technology Laboratory

Overview

The Quantum Science and Technology Laboratory will contribute to the exploration of the quantum science field and the development of new technologies for overcoming the conventional information processing limits with quantum-enabled devices and systems. With quantum information theory and our experimental research in photonic, semiconductor, and superconducting systems as a basis, we aim to achieve new technologies in the areas of quantum communication, quantum sensing, optical oscillator-based computing, and quantum computing based on superconducting circuits and topological phenomena.

Groups and Research Themes

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.

Superconducting Quantum Circuits Research Group

Superconducting Quantum Circuits

Manipulating quantum states using superconducting devices

Ultimate Quantum Measurement and Sensing

Highly sensitive measurement technologies using quantum mechanical effects

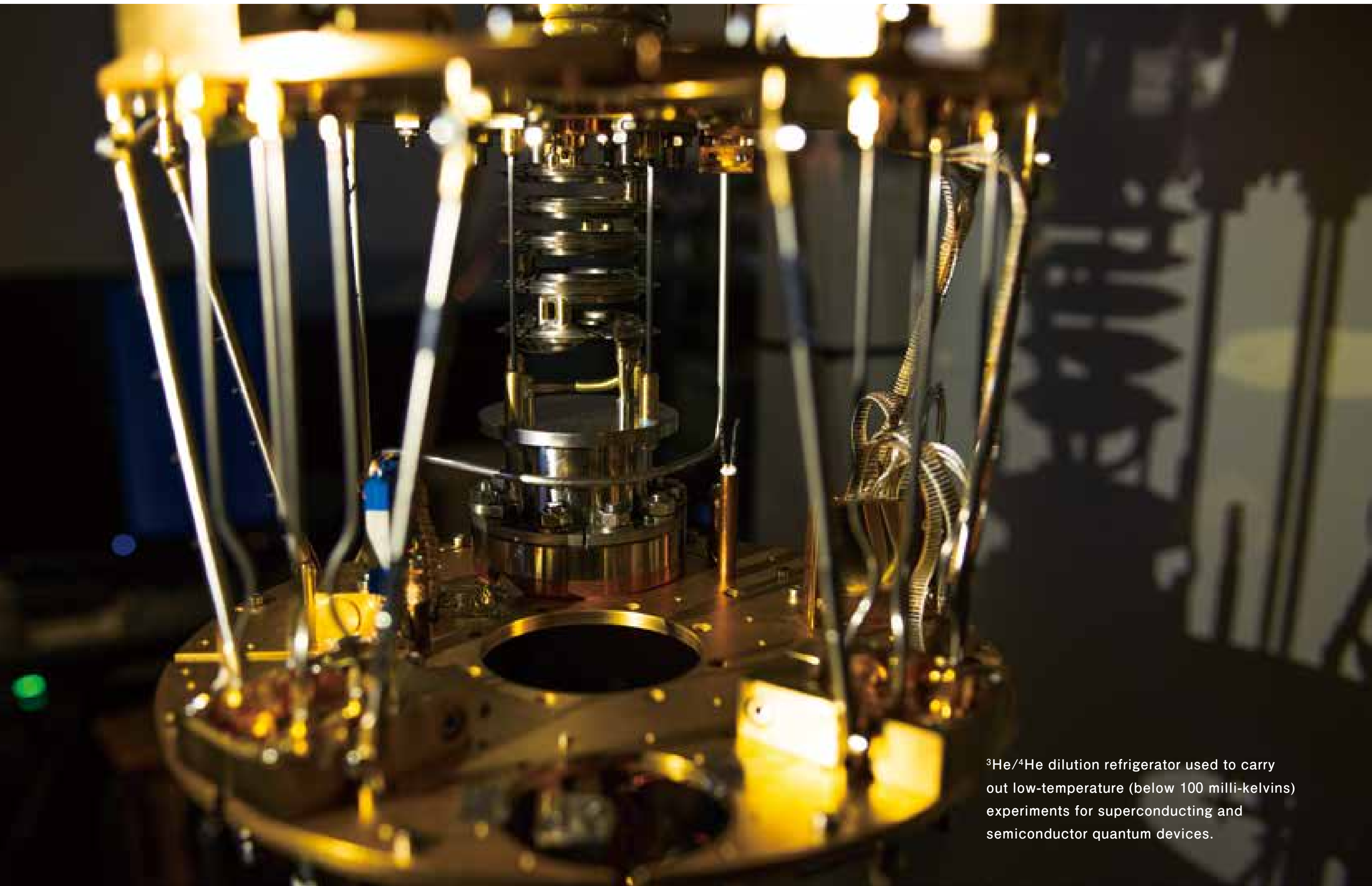
Quantum Solid State Physics Group

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

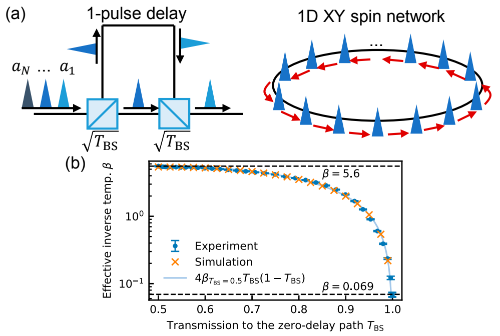
Unconventional charge and spin transport phenomena in quantum devices

Fast Coherent Carrier Dynamics in Electronic Devices

Information processing with coherent electron motion



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

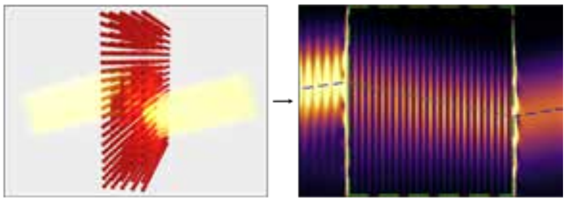


(a) Implementation of one-dimensional XY spin network with a 1-pulse delay interferometer.
(b) Effective inverse temperature as a function of the transmission on the zero-delay path.

All-optical Coherent XY Machine with Planar Lightwave Circuit Interferometers

A coherent XY machine (CXYM) is a physical system that can simulate the XY model by mapping continuous XY spins onto continuous phases of non-degenerate optical parametric oscillator (NOPO) pulses. Here, we demonstrated a large-scale (>47,000 spins) one-dimensional XY spin network with the all-optical method based on a integrated planar lightwave circuit (PLC) interferometer and controlled the effective temperature within two orders of magnitude. Once we have extended our method to more complex interactions, the all-optical CXYM will pave the way for observing topological phenomena of the XY model and exploring continuous-variable information processing.

Y. Yonezu, K. Inaba, Y. Yamada, T. Ikuta, T. Inagaki, T. Honjo, and H. Takesue, Optics Letters 48, 5787-5790 (2023).

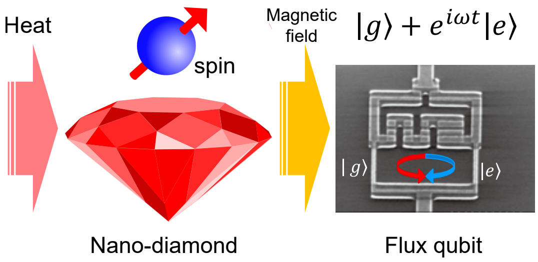


(Left) Neutral atoms are trapped by lasers to form a lattice, which is illuminated by a beam of light.
(Right) Negative refraction is observed in terms of the negative angle of the beam deflection.

Negative Refraction of Light in an Atomic Medium

Negative refraction makes light bend in the opposite direction to what is usually observed in nature. This simple change entails possibilities for transformative technologies including cloaking and superlensing, which have driven the development of artificially structured metamaterials. However, intrinsic non-radiative losses and fabrication imperfections still constrain potential applications. Here, we demonstrate that negative refraction of light is possible, without metamaterials, in cooperatively responding lattices of neutral atoms. Our work establishes atomic media as a promising alternative to metamaterials for developing powerful technologies based on negative refraction.

L. Ruks, K.E. Ballantine, and J. Ruostekoski, Nat. Commun. 16, 1433 (2025).

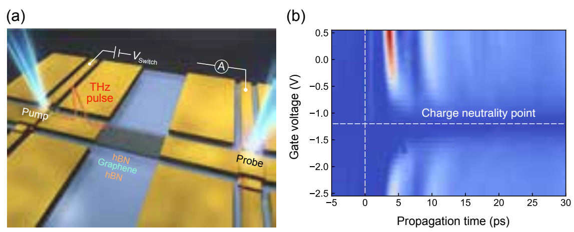


The polarization of the electron spin in the nanodiamond changes due to heat from the object to be measured. The magnetic field change caused by the polarization change is detected using the phase of the superconducting flux qubit.

Highly Sensitive Temperature Sensing Using a Microthermometer

Miniaturization of thermometers has the advantage of reducing the heat capacity of the thermometers themselves and reducing the influence of measurement on the object to be measured, but it has the problem of lowering sensitivity. By improving sensitivity through quantum sensing using a quantum hybrid system consisting of nanodiamonds and a superconducting flux qubit, we have succeeded in detecting temperature changes of several microkelvin in a very small region. This achievement not only enables quantum sensing of the physical quantity of temperature with a superconducting qubit, but also will be useful in situations where physical properties have to be measured at low temperatures.

H.Toida, ED4-1-INV ISS2024 (2024).
K. Kakuyanagi, H. Toida, L. V. Abdurakhimov, and S. Saito New J. Phys. 25 (1), 013036 (2023).



(a) Schematic diagram of THz electronics.
(b) Time domain waveform of graphene plasmon wavepackets.

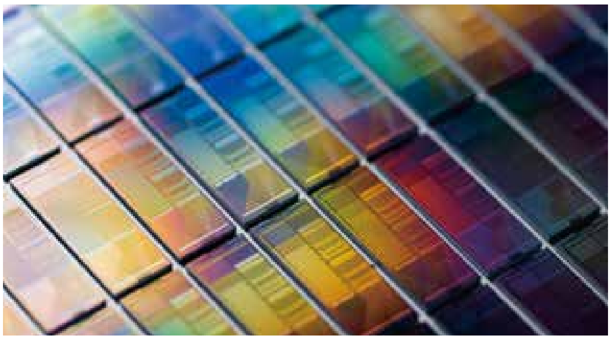
On-Chip Transfer of Ultrashort Graphene Plasmon Wavepackets

Graphene plasmons in the terahertz (THz) range are expected to play a pivotal role in next-generation high-speed circuits due to their low-loss nature and tunability through application of an external voltage. However, past studies have predominantly focused on measuring static standing waves, leaving a significant gap in our understanding necessary for circuit applications. Here, we have developed THz electronics capable of generating, controlling, and measuring the propagation of graphene plasmon wavepackets on-chip and have achieved the shortest pulse width to date of 1.2 picoseconds. Furthermore, we unveiled the propagation characteristics of these wavepackets. This achievement is a crucial step toward the realization of graphene plasmonic circuits.

K. Yoshioka, G. Bernard, T. Wakamura, M. Hashisaka, K. Sasaki, S. Sasaki, K. Watanabe, T. Taniguchi, and N. Kumada, Nat. Electron. 7, 537 (2024).

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.

Research Themes

- **Extreme enhancement of light-matter interactions by using photonic crystals and plasmonics**
- **Integrable nanophotonic devices with extremely small energy consumption**
- **Novel optical platforms using nanomaterials and nanophotonics**
- **Nanophotonic computations with photonics-electronics convergence**

Research Center for Theoretical Quantum Information

Research Center for Theoretical Quantum Information

Overview

The research center was established in October 2023 by expansively reorganizing the Research Center for Theoretical Quantum Physics, in order to further strengthen the theoretical research on quantum information science by facilitating interdisciplinary collaboration among researchers in diverse layers in the realm of quantum information. We are aiming to become a "compass" of quantum information that points to the correct direction in which the progress of quantum information technology, ranging from hardware to middleware and applications, should head by describing the future of information technology.

Research Themes

- **Cryptographic techniques using quantum information, post-quantum cryptography**
- **Quantum algorithms and quantum communication protocols**
- **Quantum computer architecture, fault-tolerant quantum computer technologies, quantum repeaters**
- **Theoretical physics aimed at quantum information processing**

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 related NTT laboratories collaborate with the goal of creating data-driven medicine using ICT and AI. The BMC engages in basic and applied research on AI analysis 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.

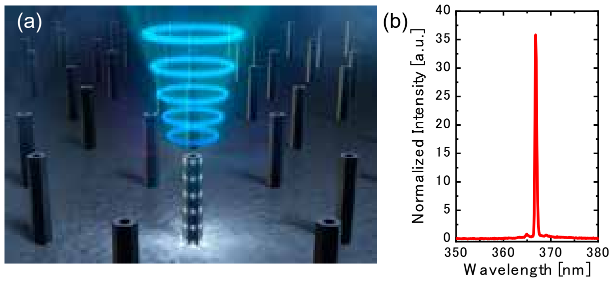
Research Themes

- **Personalized medicine by AI analysis of personal medical data (precision medicine)**
- **Cardiac modeling and rehabilitation activities supported by AI-tele stethoscope and hitoe® ECG measurement**
- **Lifestyle-related disease management based on noninvasive blood glucose sensor and core body temperature sensor**
- **Fabrication of implant materials and artificial neural networks that complement biological functions**

Vector Beam Generation from Standing Hollow GaN Nanowire Lasers

Semiconductor nanowires are functional materials with one-dimensional structures, and they are expected to be used in nano-optical devices such as nanolasers. We have fabricated hollow GaN nanowires by using the sublimation method and have confirmed that they show lasing oscillation. Furthermore, by optimizing the structure, we generated a vector beam with a hollow electric field and azimuthally polarized light. The findings of this research will be useful for studying topological light and as a new on-chip light source.

M. Takiguchi, S. Sergent, B. Damilano, S. Vézian, S. Chenot, N. Yazigi, P. Heidt, T. Tsuchizawa, T. Yoda, H. Sumikura, A. Shinya, and M. Notomi, ACS Photonics, 11, 789 (2024), Featured in New scientist.

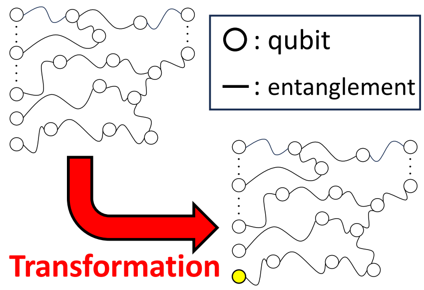


(a) Schematic diagram of hollow nanowire lasers.
(b) Lasing spectrum.

Transformation to the most Powerful Quantum Computer via Replacement of a Single Qubit

Quantum computers have two kinds of output: bits and qubits. It would be unrealistic for the first goal to be realization of a universal quantum computer. As an alternative idea, it is worth considering that we first build a “weak” quantum computer, which can generate any state of bits, but only a restricted set of quantum states, before attempting to realize a universal one through improving the weak one. However, it is not yet known how to transform a weak quantum computer into a universal one. Here, we have theoretically constructed such a transformation by simply replacing a single qubit in a given weak quantum computer with another qubit.

Y. Takeuchi, Phys. Rev. Lett. 133, 050601 (2024).

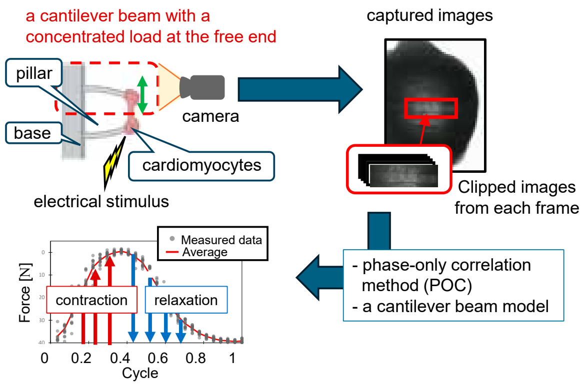


Schematic diagram of our transformation method applied to measurement-based quantum computation, which is a computing model suitable for optical quantum computation. A single qubit is replaced with another qubit highlighted by yellow color.

Measurement of Mechanical Performance of Engineered Heart Tissue with POC-Based Video Analysis

In research aimed at elucidating the causes of diseases and therapies using engineered heart tissues (EHTs) derived from disease-specific induced pluripotent stem cells (iPSCs), accurately measuring contraction and relaxation forces is important. To address this issue, we developed a method based on phase-only correlation (POC) to measure contractile and relaxation forces. This method involves culturing cardiomyocytes on a pair of pillars with known mechanical properties and capturing video of tissue movement in response to cyclic electric stimuli under a microscope. By tracking tissue movement across video frames, the method calculates the maximum deflection and frequency of the pillars by fitting the detected deflection to a sine function. Our results demonstrate that this approach enables precise measurement of the mechanical performance of EHTs.

M. Hasegawa, K. Miki, T. Kawamura, I. Takei-Sasozaki, Y. Higashiyama, M. Tsuchida, K. Kashino, M. Taira, E. Ito, M. Takeda, H. Ishida, S. Higo, Y. Sakata, and S. Miyagawa, Dev.Growth Differ. 66(2), 119-132 (2024).



(1) Culturing cardiomyocytes on a pair of pillars with known mechanical properties,
(2) Capturing video of tissue movement in response to cyclic stimuli using a microscope,
(3) Detect deflections between the first frame and each frame by using POC-based method,
(4) Convert to force based on a cantilever beam model.

NTT Fellow

「"Fellow" is a position given to highly esteemed researchers elected from among the employees who have made their mark globally and whose distinguished achievements in research have already received worldwide recognition. A fellow heads a research team and is responsible for driving forward innovative research in a critical area that has global significance.」

Shingo Tsukada

Medicine, Physiology, Biomedical Interface & Data Analysis

Research Subject

Biological Information Elucidation Using Advanced Medical Materials

He has been engaged in the study of mechanism and activity control of signal transduction of brain cell. His current interests are the detection of biomedical signals using novel wearable-type and implant-type bioelectrodes based on the composites of conductive polymers with various fibers and textiles. He invented the Tensor Cardiography (TCG). He was appointed as Fellow since April 1, 2018.

Hiroshi Yamaguchi

Quantum and Nano Device Research

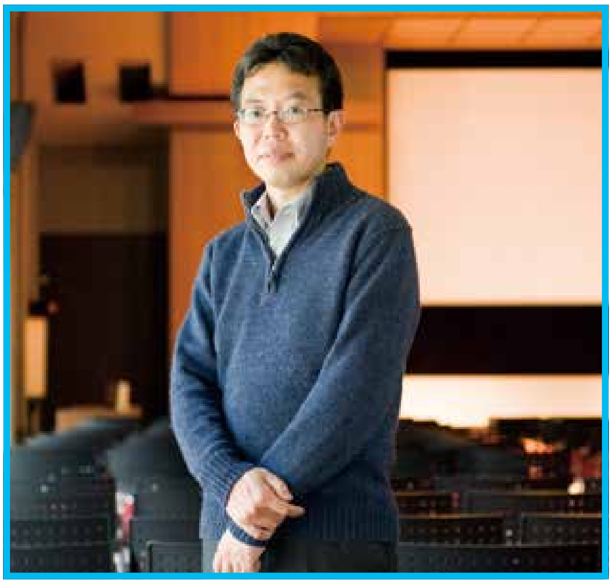
Research Subject

Nano-mechanics in Semiconductors

He has been engaged in the study of nanomechanical devices, which exhibit novel functionalities reflecting their mechanical vibrational properties. He was appointed as Fellow since March 22, 2022.

Masaya Notomi

Nanophotonics Center Project Manager



Research Subject

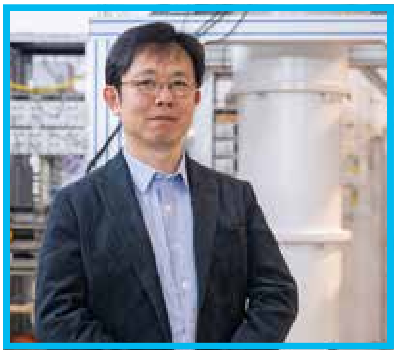
Photon Manipulation in Photonic Nanostructures

His research interest has been to control the optical properties of materials and devices by using artificial nanostructures and engaged in research on quantum wires/dots and photonic crystal structures. He was appointed as Fellow since April 1, 2023.

December 31, 2024

Senior Distinguished Researcher

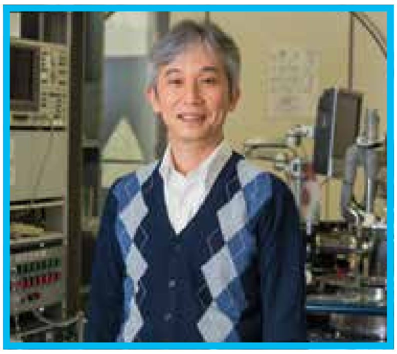
Koji Muraki



Research Subject

Electron Correlation in Semiconductor Nanostructures

Akira Fujiwara

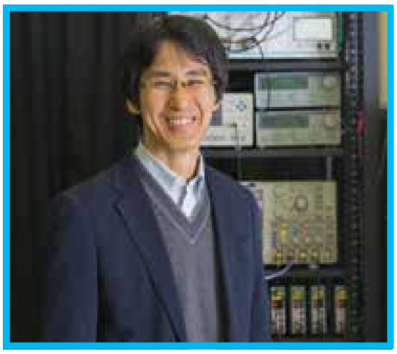


Research Subject

Ultimate Electronics Using Semiconductor Nanostructures

Hiroki Takesue

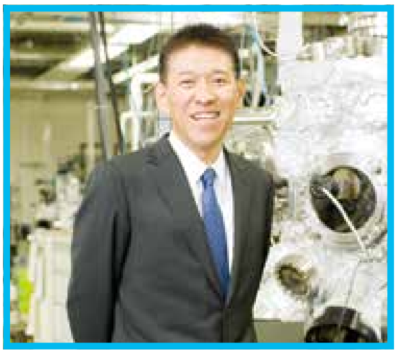
Quantum Science and Technology Laboratory Executive Manager



Research Subject

Quantum Communication Experiments in Telecommunication Band
Coherent Ising Machine

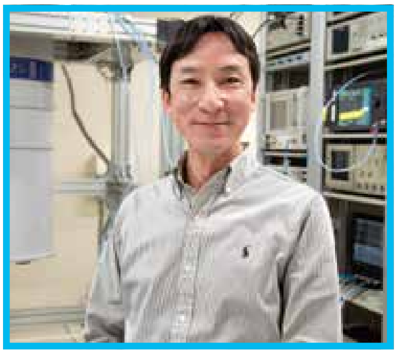
Hideki Yamamoto



Research Subject

Design and Thin-film Synthesis of Novel Superconductors and Magnetic Materials with Elucidation of the Underlying Physics

Shiro Saito



Research Subject

Quantum Information Technologies Based on Superconducting Quantum Circuits

Yoshitaka Taniyasu

Low-Dimensional Nanomaterials Research Group Leader

Research Subject

Research on Functional Materials for Green Innovation

Norio Kumada

Quantum Solid State Physics Research Group Leader

Research Subject

Ultrafast electron dynamics in two-dimensional systems

Distinguished Researcher

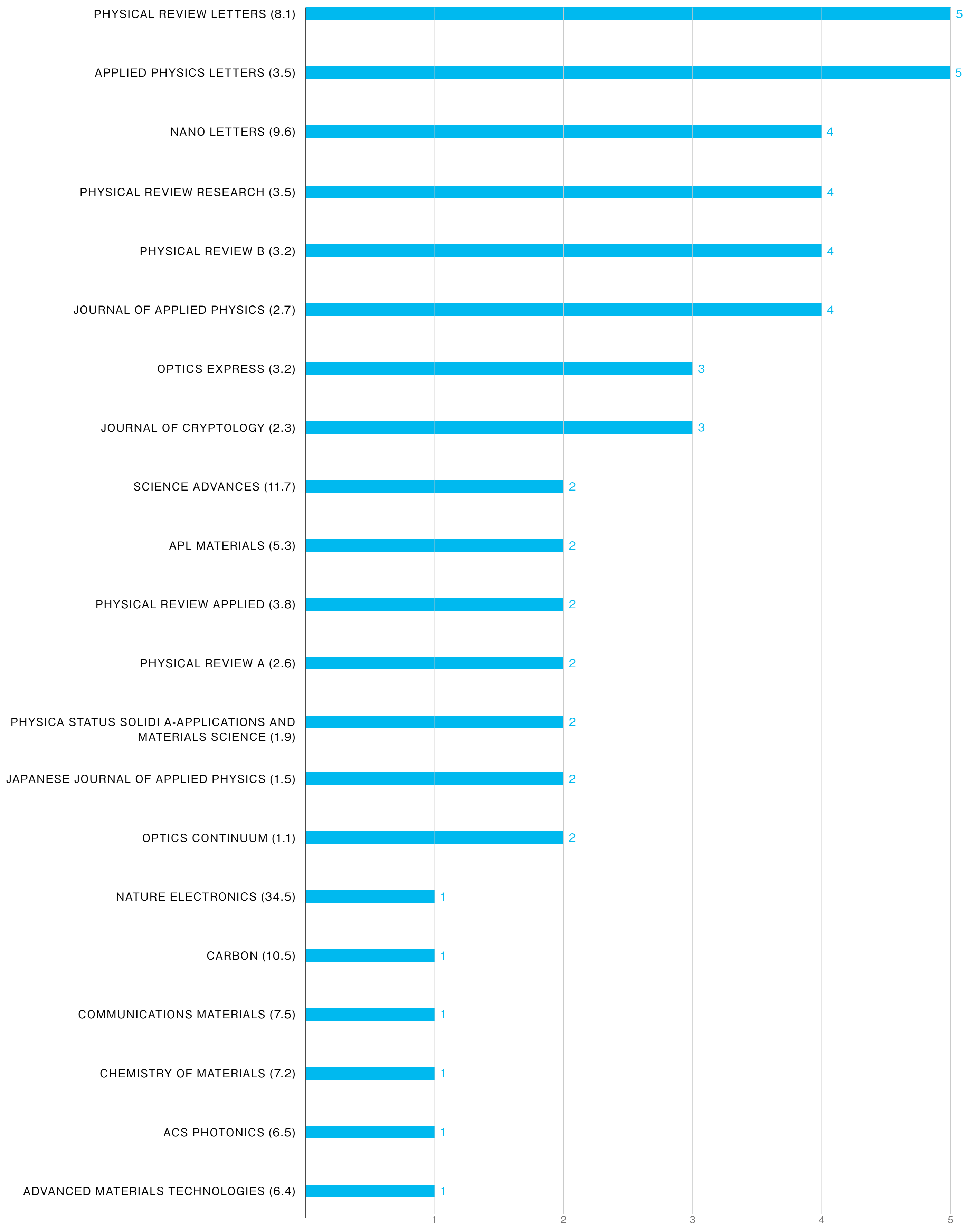
Katsuhiko Nishiguchi
Imran Mahboob
Haruki Sanada
Koji Azuma
Takahiro Inagaki
Hajime Okamoto

Associate Distinguished Researcher

Yuki Wakabayashi
Motoki Asano

Publication List

The total number of NTT Basic Research Laboratories papers published in international journals in 2024 is 83 with an average impact factor of 4.483. The 2023 impact factor of those individual journals are shown in ( ).



Number of Presentations

228
(64 Invited talks)

Conferences	Numbers
International School and Symposium on Nanodevices and quanTum Technologies (ISNTT2024)	32
Conference on Lasers and Electro-Optics (CLEO2024)	13
36th International Conference on the Physics of Semiconductors (ICPS)	12
14th International Conference on Metamaterials, Photonic Crystals and Plasmonics (META2024)	7
2024 APS March Meeting	7
The 23rd International Conference on Molecular Beam Epitaxy (ICMBE2024)	7
37th International Microprocesses and Nanotechnology Conference (MNC2024)	6
IEEE Silicon Photonics Conference 2024	6
12th International Workshop on Nitride Semiconductors (IWN2024)	5
2024 MRS Fall Meeting & Exhibit	5
Optical Fiber Communication Conference and Exposition (OFC2024)	5
QCrypt 2024	5

Number of Patents

121

List of Award Winners

JSAP Outstanding Paper Award
Buckling-induced Quadratic Nonlinearity in Silicon Phonon Waveguide Structures **Megumi Kurosu**

The Laser Society of Japan, Encouragement Award
Ultralow Latency Operations Based on Linear Photonics Toward Photo-Electronic Converged Data Processing Infrastructure **Shota Kita**

MWPTHz Young Scientist Paper Award
On-chip Readout of Ultrafast Charge Dynamics in Graphene Using Terahertz Electronics **Katsumasa Yoshioka**

IOP Trusted Reviewer Status
Takuya Ikuta

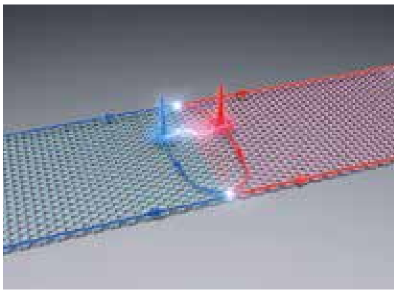
IEEJ Electronics, Information and Systems Society Quick Paper Review Promotion Award
Koji Sakai

The Society of Life Support Engineering, LIFE2024 Young Presenter Award
Self-folding Microelectrode Array for Electrical Recordings from in Vitro Modular 3D Neuronal Network **Koji Sakai**

JSAP Molecular Electronics and Bioelectronics Encouragement Award
Self-Folding Graphene-Based Interface for Brain-Like Modular 3D Tissue **Koji Sakai**

The 43rd Electronic Materials Symposium, EMS Award
Ferromagnetic Permalloy/B-doped Diamond Schottky Tunnel Contacts Toward Spintronic Device Applications **Makoto Kawano**

News Release

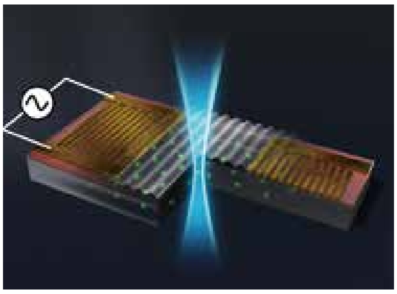


2024.01.16

Demonstration of Electron Flying Qubit Operation

- Manipulation of Quantum Superposition States of Propagating Single Electron in Graphene -

Quantum Solid State Physics Research Group

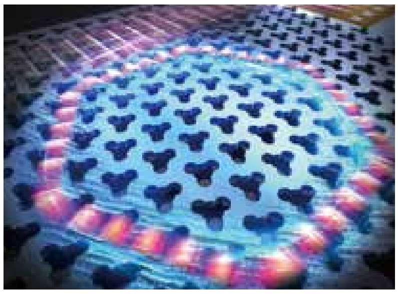


2024.01.19

Hybrid State of Electrons Resonating at an Optical Communication Wavelength and a Gigahertz Ultrasonic Wave

- Anticipates the Development of Energy-saving Quantum Optical Memory Devices Using Ultrasonic Waves -

Nanomechanics Research Group

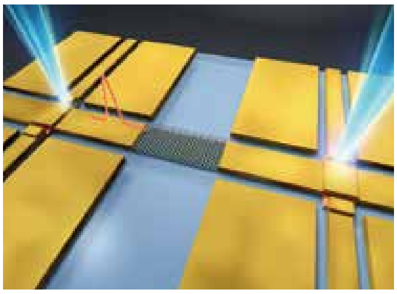


2024.07.16

First Gigahertz Ultrasonic Circuit that uses the Principle of Topology

- Realization of Elemental Technologies for Miniaturization and Higher Performance of Radio Frequency Filters for Wireless Communications -

Nanomechanics Research Group

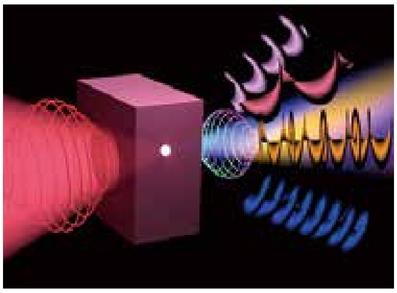


2024.07.22

Electrical Generation, Propagation Control, and Detection of the Ultrashort Graphene Plasmon Wave Packets

-Contributing to the Realization of Ultrahigh-speed Signal Processing at Terahertz Frequency-

Quantum Solid State Physics Research Group

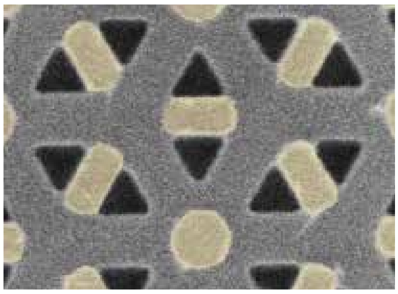


2024.08.21

First Successful Simultaneous Control of Optical Polarization and Wavefront Shaping in High-harmonic Generation

- Clarification of the Control Law of Light Widely Related to Spectroscopy, Laser Processing, Optical Tweezers, Information and Communication, etc. -

Quantum Optical Physics Research Group

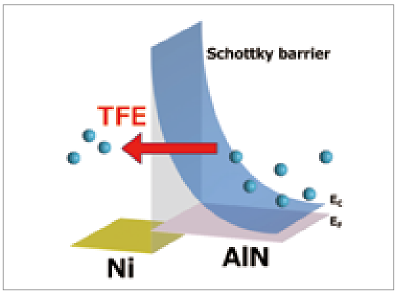


2024.09.06

Photonic Topological Phase Transition Achieved by Material Phase Transition

- Promising for Reconfigurable Functional Photonic Integrated Circuit Technologies -

Photonic Nano-Structure Research Group



2024.12.10

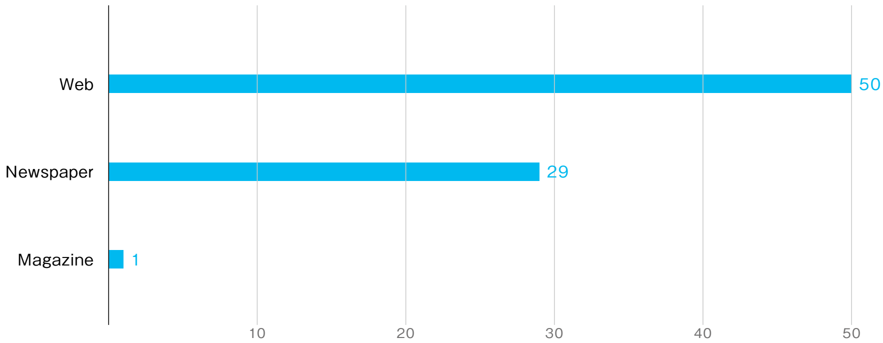
Ideal Current Transport in Ultrawide Bandgap (UWBG) Aluminum Nitride (AlN) Schottky Barrier Diode Has Been Discovered and Revealed!

- Toward Realizing High-Efficiency Power Semiconductor Devices that Contribute to a Low-Carbon Society -

Thin-Film Materials Research Group

Number of News Reports

80



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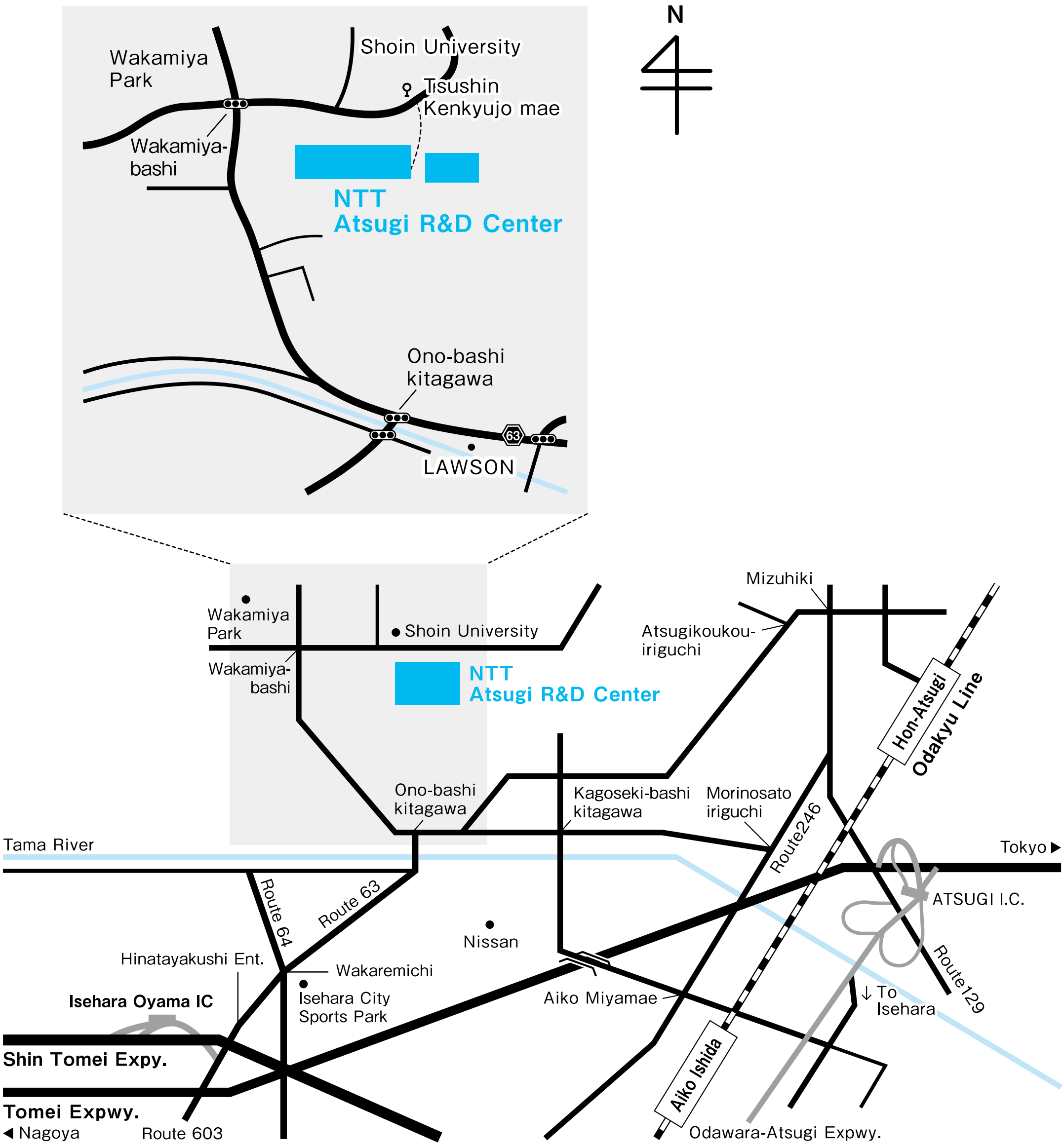

Access

By train and bus

"Aiko-Ishida" station on Odakyu Line (About 50 minutes from Shinjuku by Rapid Express / Express)
North Exit Bus Depot 4
20 minutes bus ride on "愛17 Morinosato" route; get off at "Tsushin Kenkyujo-mae" bus stop.
20 minutes bus ride on "愛18 Shoin Daigaku" route; get off at "Tsushin Kenkyujo-mae" bus stop.
20 minutes bus ride on "愛19･21 Nissansenshingijyutsukaihatsu center" route; get off at "Tsushin Kenkyujo-mae" bus stop.

"Hon-Atsugi" station on Odakyu Line (About 50 minutes from Shinjuku by Rapid Express / 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 2,000yen) or 20 minutes from "Hon-Atsugi" station on Odakyu Line (around 3,000yen)

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.
10 minutes (5km) drive from Shin Tomei Expwy "Isehara Oyama I.C."; exit the Expwy, turn left onto Route 603, then Route 63, left at Onobashi, right at Wakamiyabashi.

NTT Basic Research Laboratories

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