

Basic Research Laboratories

NTT, Inc.

Annual Report

2025

NTT
BASIC
RESEARCH
LABORATORIES



Message from the NTT-BRL Director-General 2025

I am pleased to present the 2025 Annual Report of NTT Basic Research Laboratories (NTT-BRL).

Since the publication of our first report in 1990, this marks the 36th issue. That we are able to continuously share our basic research activities with readers around the world is possible only through the generous and sustained support of our partners and stakeholders. On behalf of the institute, I would like to express my sincere appreciation.

The roots of our laboratories trace back to the establishment of NTT-BRL in 1985, coinciding with the privatization of NTT. From its inception, NTT-BRL has been guided by a clear commitment: to create globally significant knowledge and concepts that advance academic disciplines centered on telecommunications and information science, and to provide the seeds of next-generation technologies. This founding spirit continues to live on today as a shared belief among our researchers— We will create a deeper understanding of nature, expand NTT-BRL's possibilities, and create a compass for a better world. Over the past four decades, technologies in telecommunications and information science have advanced dramatically and become deeply embedded in society. Their influence now extends far beyond their original domains, intersecting with energy, computing, security, sensing, materials, biomedical science, and artificial intelligence. At the same time, global political, economic, and social environments have undergone profound changes, reshaping expectations for basic research and the responsibilities of research institutions.

In this evolving landscape, NTT-BRL brings together experts in physics, chemistry, biology, mathematics, electrical engineering, information science, and medicine to address frontier challenges in materials science, condensed matter physics, and quantum science. We continue to push the boundaries of knowledge and technology while pursuing meaningful contributions to society. Equally important is our commitment to openness: through close collaboration with universities and research institutions worldwide, we strive to remain a research laboratory open to the world, united by shared curiosity and purpose.

In 2025, we achieved several notable milestones. We demonstrated efficient magnetization switching using thin-film magnets based on the Weyl semimetal oxide SrRuO_3 and advanced the application potential of high-quality materials such as ultra-wide-bandgap AlN for high-power millimeter-wave transistors. In quantum science, we proposed new theories of optical quantum operations and protocols for high-speed, long-distance quantum communication, helping to shape the emerging field of the quantum internet.

In addition, we organized and co-organized a wide range of academic events, from long-established international conferences and workshops—both longstanding and newly proposed—such as Frontiers of Nanomechanical Systems (FNS2025), the SIP3 Quantum Technology Workshop “The Future Enabled by Ultra-Precise Optical Frequencies”, and the 53rd Quantum Information Technology Meeting (QIT53). Through these activities, we provided important opportunities for researchers and students from around the world to gather at our Atsugi R&D Center, engage in active exchanges, and build lasting friendships. Complementing these occasions, our regularly held BRL Seminar Series continued to play a central role in our daily research activities. This year, we hosted 36 seminars, featuring outstanding researchers from Japan and abroad who shared their latest research achievements with us.

Looking ahead, in January 2026 we plan to hold the 40th Anniversary Symposium of NTT-BRL, together with the 13th NTT-BRL Advisory Board Meeting, composed of internationally renowned scientists. These initiatives will offer us an important opportunity to reflect deeply on the value and role of basic research today, while further strengthening and refining our own research activities.

We at NTT-BRL have never forgotten our origins and are always looking to the future of the world.

We would like to express our sincere appreciation for your continued guidance and support.



Katsuya Oguri

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

Advisory Board

The aim of the Advisory Board is to provide a critical and objective evaluation of our research plans and activities. This enables us to employ strategic management in a timely manner. Proposals and advice received at this biennial board meeting are reflected in our actual ongoing research and its management. The 13th meeting will be held on-site in January 2026, and we are planning to report our latest research results and received valuable feedback.



Hosting International Symposia and Related Events

NTT Basic Research Laboratories serves as an open research hub by fostering interaction among leading researchers and students from Japan and around the world through the hosting and organization of international conferences and workshops.

Frontiers of Nanomechanical Systems 2025 (FNS2025)

The 5th meeting of Frontiers of Nanomechanical Systems (FNS2025), an international workshop in the field of nano- and micro-electromechanical systems (NEMS & MEMS), was held from June 3 to 6, 2025. During the workshop, 160 participants attended, and invited and contributed presentations were delivered.



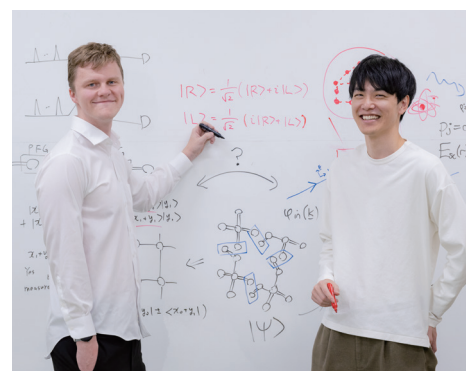
The 53rd Quantum Information Technology Symposium (QIT53)

The 53rd Quantum Information Technology Symposium (QIT53), aimed at promoting research exchange in the field of quantum information science, was co-hosted from December 2 to 4, 2025. During the symposium, 166 researchers and students participated, and active discussions were held across a wide range of disciplines, including information science, physics, optical science, and mathematical science.

Front image:

Atomic optical media

Negative refraction bends light in the opposite direction to that usually observed in nature, entailing possibilities for technologies such as cloaking and superlensing. Its promise has driven the development of artificially structured metamaterials, but at optical frequencies their performance is constrained by intrinsic non-radiative losses and fabrication imperfections. At Basic Research Laboratories, we theoretically demonstrated that negative refraction can be observed without metamaterials, in cooperatively responding atoms arranged in a lattice. This feat was made possible by establishing large-scale, microscopic simulations of atoms interacting through light, allowing researchers to pinpoint the emergence of negative refraction in the intensity of beams propagating through a variety of atomic media. These results highlight atomic lattices as a pristine and powerful platform for deepening our understanding of optics and exploring applications beyond the metamaterial paradigm. To this end, we are further investigating the experimental signatures of negative refraction towards eventual realizations and exploring its near-term potential.



Lewis Ruks (left)

Engaged in theoretical research on microscopic modeling of quantum optical systems

Tomohiro Yamazaki (right)

Engaged in theoretical research on photonic quantum information processing

Organization

Vice President, Head of
Basic Research Laboratories, NTT, Inc.

Katsuya Oguri



Research Planning Section

Executive Manager
Masumi Yamaguchi



Multidisciplinary Materials Design and Science Laboratory

Executive Manager
Masumi Yamaguchi

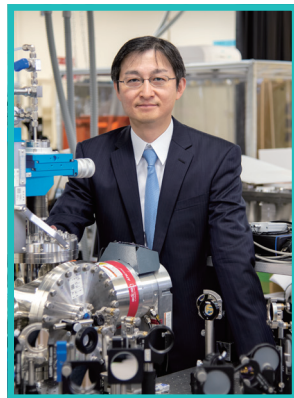


→ P5

- 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)…104(12)
- Postdoc…11*
- Joint-Researchers…27* ●Domestic Interns…8*
- International Interns…24* ●Invited Professor…1*
- Guest Researchers…1* ●TQC Visitors…10*

*…Jan-Dec 2025 total

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



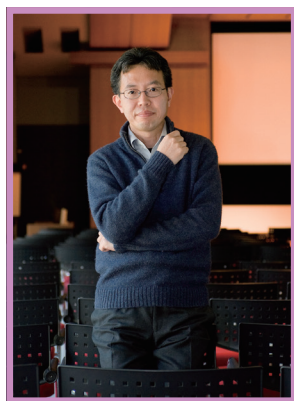
CEA Saclay, France
Prof. Christian Glattli



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, Professor Emeritus

Prof. Junsaku Nitta

Tohoku University

Prof. Masao Morita

Hiroshima University

Prof. Hideki Gotoh

University of Toyama

Prof. Kiyoshi Tamaki

→ Multidisciplinary Materials Design and Science Laboratory

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

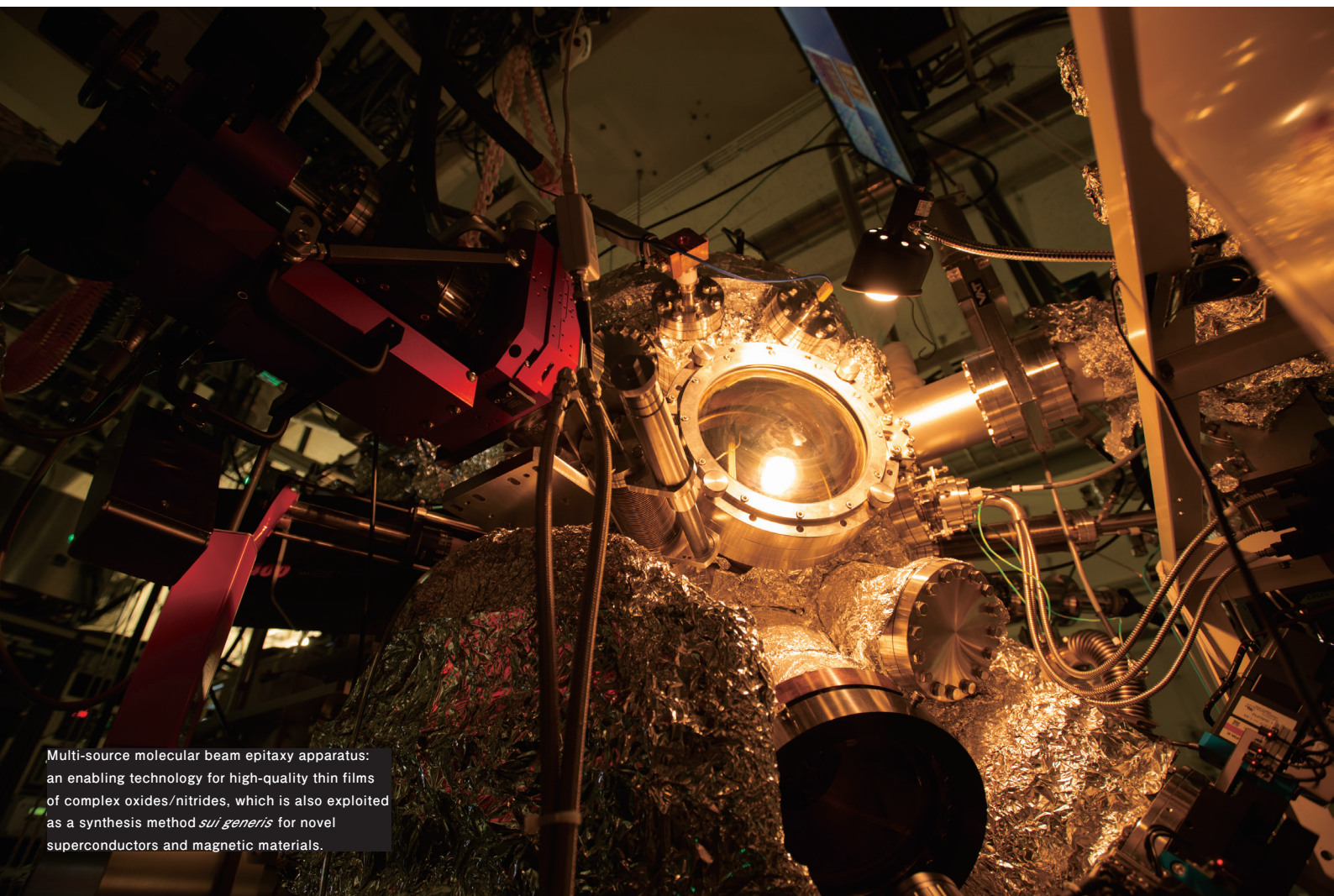
Molecular and Bio Science Research Group

Biocompatible Electrode Materials

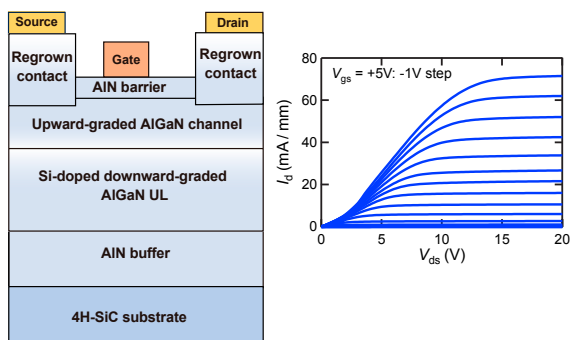
Development and application of bioelectrode materials for measurement of deep biological information

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.

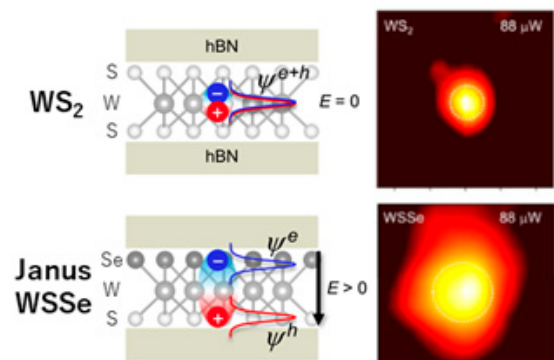


Device structure of AlN-based polarization-doped FET with downward-graded AlGaN underlayer and its measured I_d - V_{ds} characteristics

AlN-based Polarization-doped Field-effect Transistors with Downward-graded AlGaN Underlayer

We fabricated AlN-based polarization-doped field-effect transistors (PoLFETs) with high-Al-content AlGaN channels. To suppress the depletion of the channel region, a downward-graded AlGaN underlayer (UL), in which the Al composition decreases toward the surface, was introduced beneath the channel, resulting in high sheet electron concentration of $7.2 \times 10^{12} \text{ cm}^{-2}$. The PoLFET with the downward-graded AlGaN UL showed a drain current of 70 mA/mm and high on/off current ratio of 10^8 .

M. Hiroki, K. Hiram, K. Kumakura, and Y. Taniyasu, *Appl. Phys. Lett.* 126 (20), 202108 (2025).

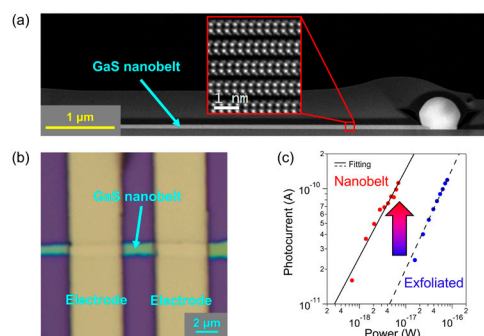


Exciton-emission images ($10 \mu\text{m} \times 10 \mu\text{m}$) of Janus TMDC (WSSe) and conventional TMDC (WS_2)

Exciton Dynamics Driven by Broken Symmetry in Janus Transition Metal Dichalcogenides

Janus transition metal dichalcogenides (TMDCs) consist of different chalcogen atoms on the top and bottom layers surrounding the transition metal atoms. This structural asymmetry breaks the mirror symmetry of the crystal and gives rise to physical properties distinct from those of conventional TMDCs. In Janus TMDCs, we found that the exciton-diffusion length increases to nearly twice that of conventional ones. This enhancement originates from the intrinsic out-of-plane electric field induced by crystal asymmetry, which spatially separates electrons and holes. These results provide new design principles for tailoring the physical properties and offer important insights toward excitonic devices.

U. Erkilic, S. Wang, Y. Sekine, T. Taniguchi, K. Watanabe, and Y. Taniyasu, *Nano Lett.* 25 (32), 12193 (2025).

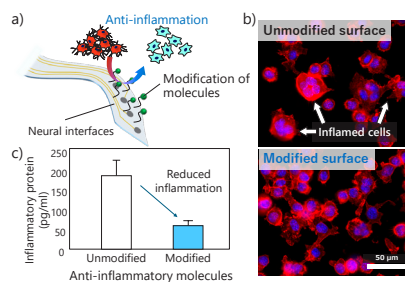


(a) Cross-sectional transmission electron microscopy image of GaS nanobelt. (b) Micro-scale photodetector based on GaS nanobelt. (c) Incident light power dependence of photocurrent of GaS nanobelt and flake photodetectors (bias voltage: 5V).

Synthesis of GaS Semiconductor Nanostructures and Demonstration of High-sensitivity Micro-optical Devices

Group III-VI atomic-layered semiconductors, including GaS, offer wide bandgap tunability ranging from the infrared to the visible region, making them highly promising for optoelectronic device applications. We developed a technique to synthesize GaS nanobelt structures via self-catalyzed vapor-liquid-solid growth. A photodetector fabricated with these GaS nanobelts exhibited a photoresponsivity an order of magnitude higher than that of conventional mechanically exfoliated flakes. This performance enhancement is attributed to the low contact resistance achieved by the nanobelt edge-contact configuration. These results open up new possibilities for material design in group III-VI atomic-layered semiconductors and expand the potential for nano-optoelectronic device applications.

Y. Endo, Y. Sekine, and Y. Taniyasu, *Appl. Phys. Lett.* 126 (4), 043105 (2025).



(a) Neural interface surface with immobilized anti-inflammatory molecules. (b) Upper: inflamed cells on unmodified surface (white arrows: single cells (red) containing multiple nuclei (blue), characteristic inflammatory response); lower: cells on anti-inflammatory molecule-modified surface with suppressed inflammation. (c) Surface modification with anti-inflammatory molecules reduces inflammatory protein levels under inflammatory conditions.

Molecular Modification to Suppress Inflammation around Neural Devices Connecting Brain and Machines

Neural interfaces implanted in the brain are expected to serve as key technologies connecting the brain and machines; however, inflammation as a host defense response has been a fundamental challenge. Conventional approaches have been developed to suppress inflammatory responses through mechanical design, such as miniaturization and increased flexibility of interfaces, but strategies to reduce inflammation once it has been triggered remain limited. We propose a strategy to suppress peri-implant inflammation by covalently immobilizing anti-inflammatory molecules on the interface surface. Cell- and protein-based evaluations confirmed a reduction in inflammatory responses, suggesting that this strategy could contribute to the long-term stability of neural interfaces.

Y. Mizuno, K. Sakai, T. Goto, M. Yamaguchi, and A. Tanaka, *Mater. Today Commun.* 48, 113283 (2025).

→ Advanced Applied Physical Science Laboratory

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

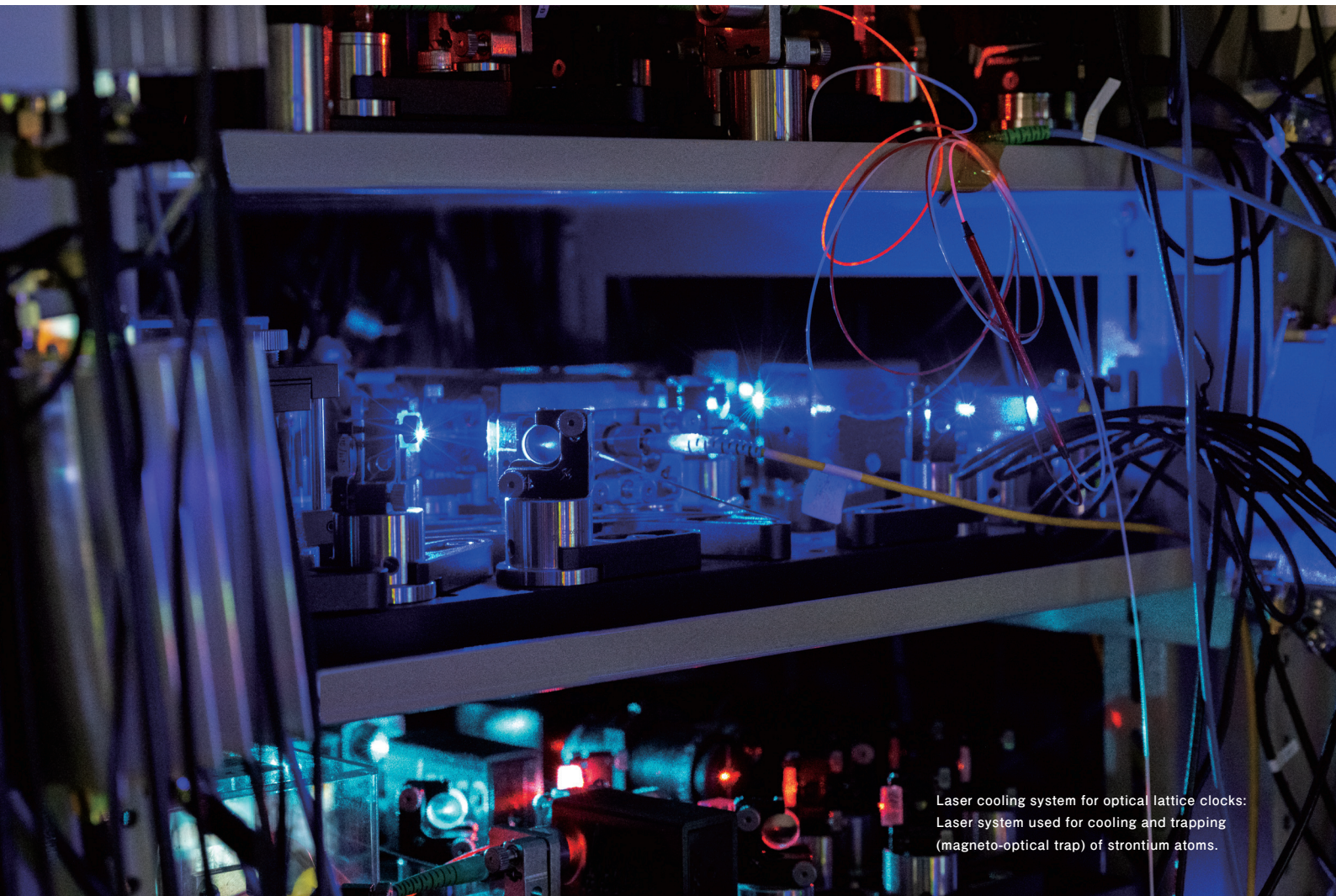
Nano-scale Physics in Optically-active Materials

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

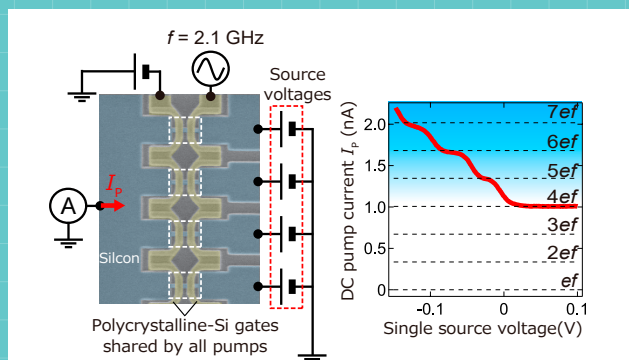
Photonic Nano-Structure Research Group

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.

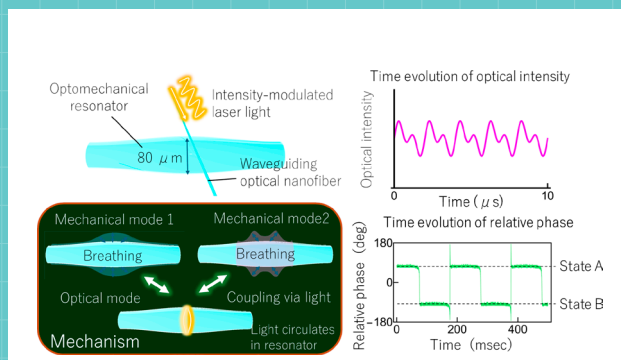


(Left) Electron micrograph of device and measurement setup. (Right) Nanoampere-level current generated by parallel operation of pumps. Currents corresponding to integer multiples of ef (where f is frequency and e is elementary charge) are produced.

Generation of Nanoampere Currents using Parallel Silicon Single-electron Pumps

A silicon single-electron pump, which transfers electrons one by one under clock control at frequency f , is expected to serve as a current standard for precise current measurements. However, the small magnitude of the output direct-current pump current has been a challenge. We addressed this issue by demonstrating parallel operation of multiple pumps. To align the optimal operating-voltage point of each pump (white squares in the figure), we developed a device structure in which the source electrode is divided, enabling individual optimization through independent source-voltage control. We thus achieved nanoampere-level current generation exceeding previous records. This represents significant progress toward a high-accuracy and practical current standard.

G. Yamahata, T. Shimizu, K. Nishiguchi, and A. Fujiwara, *Nano Letters* 25(25), 10202 (2025).

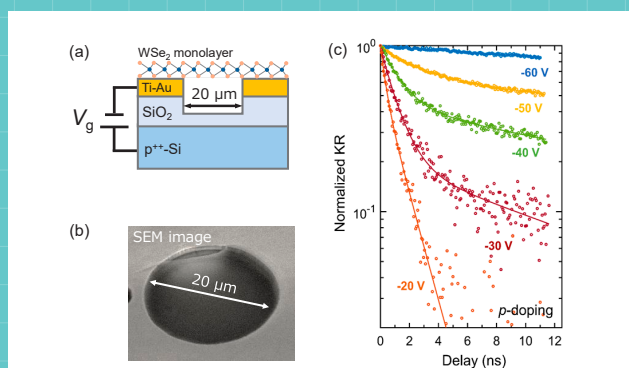


Conceptual illustration of manipulation of synchronization dynamics in mechanical oscillators using optomechanical device (left) and phase difference between two oscillators with instantaneous transitions between two synchronized states (right)

World's First Successful Real-time Optical Control of Synchronization Between Microscopic Oscillators

Synchronization, where coupled oscillators align their rhythms, is a familiar nonlinear phenomenon and a fundamental principle underlying neural networks. The coupling between oscillators has thus far been fixed by the device structure, making it difficult to manipulate the synchronization dynamics. We introduce a method that optically induces coupling in a glass-fiber optomechanical resonator, enabling optical control of synchronization dynamics in mechanical oscillators. This achievement opens the way toward novel neuromorphic technologies that emulate the dynamical behavior of neural networks.

M. Asano, H. Okamoto, and H. Yamaguchi, *Sci. Adv.* 11, eady4167 (2025).

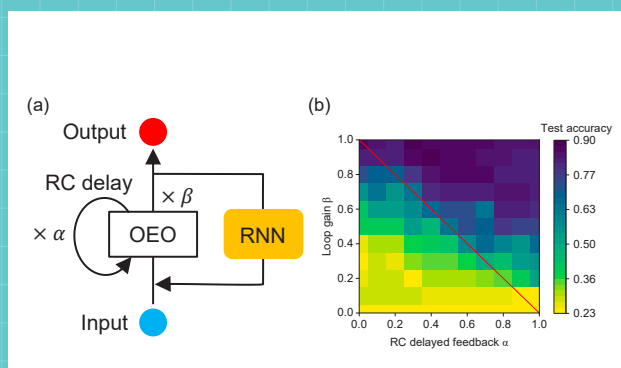


(a) Schematic of a suspended WSe_2 monolayer. (b) SEM image of the sample. (c) Time evolution of valley polarization measured via the magneto-optical effect. The decay time was modulated by the applied voltage.

Manipulation of "Valley" Information: New Degree of Freedom for Electrons in Single-layer Semiconductors

The diverse physics exhibited by two-dimensional semiconductors with atomic layer thickness has attracted attention. We are researching technologies to control "valleys", a new degree of freedom for electrons (two energy minima that appear in the band structure). In this study, we transferred a WSe_2 monolayer membrane over a $20\text{-}\mu\text{m}$ -diameter hole fabricated in a Si substrate and visualized the behavior of the valley-polarization state using the magneto-optical effect in an environment where the effects of external disturbances were suppressed. We also demonstrated that the relaxation time of information transferred to the valleys can be freely adjusted. [The results from this study?] will pave the way for applications in low-power information processing.

G. Mariani, Y. Kunihashi, L. Smet, T. Wakamura, S. Sasaki, J. Ishihara, M. Kohda, J. Nitta, and H. Sanada, *Appl. Phys. Lett.* 125, 252401 (2024).



(a) Schematic of optoelectronic RNN using OEO converters with RC delay. (b) Dependence of test accuracy on RC delayed feedback α (proportional to RC time constant) and loop gain β ($\beta < 1$ corresponds to loss) of OEO converters for sequential MNIST classification task.

Optoelectronic Recurrent Neural Network Using Optical-electrical-optical Converters with RC Delay

Optical neural networks have attracted attention because they can execute the multiply-accumulate operations of artificial intelligence and machine learning with low latency and low power consumption. In recurrent neural networks (RNNs) that execute time-series information processing, however, optical loss in the loop degrades learning accuracy. We propose an optoelectronic RNN that uses optical-electrical-optical (OEO) converters to compensate for optical loss and confirm that using the accumulation of time-series information from the RC delay of the OEO device enables us to not only suppress the degradation of learning accuracy but also compensate for it caused by optical loss. These results will lead to the realization of high-speed optical time-series processors and low-latency optical communications.

M. Arahata, S. Kita, K. Aoyama, A. Shinya, H. Sawada, and M. Notomi, *J. Lightwave Technol.* 44(2), 496 (2026).

→ Quantum Science and Technology Laboratory

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

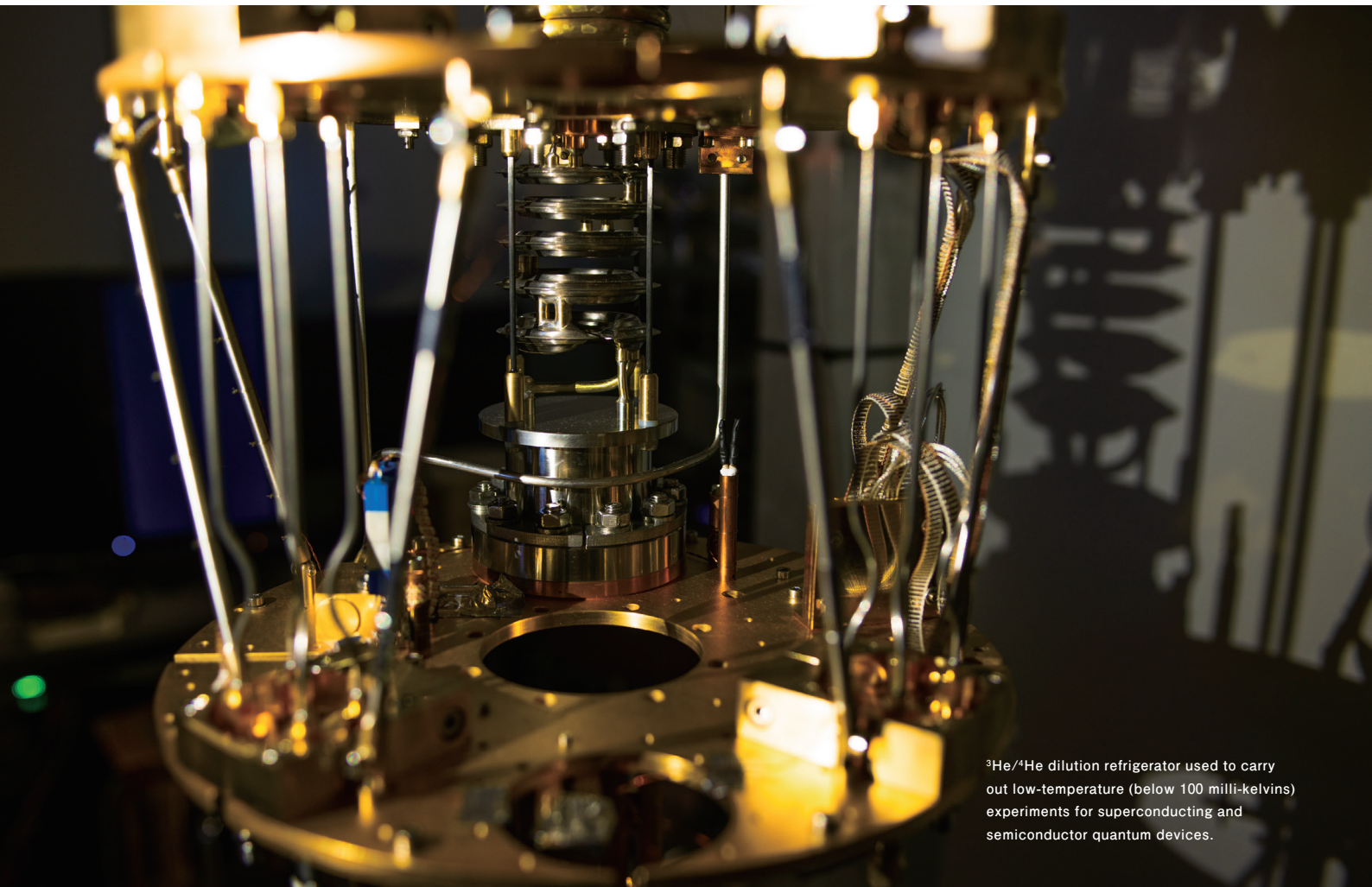
Quantum Solid State Physics Group

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

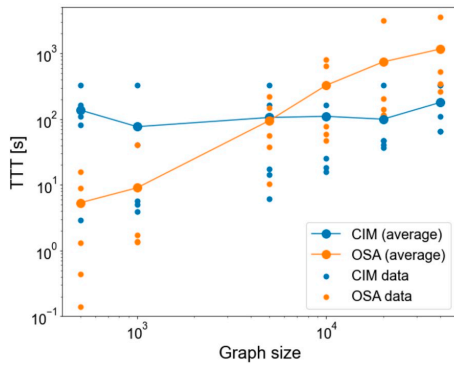
Unconventional charge and spin transport phenomena in quantum devices

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.

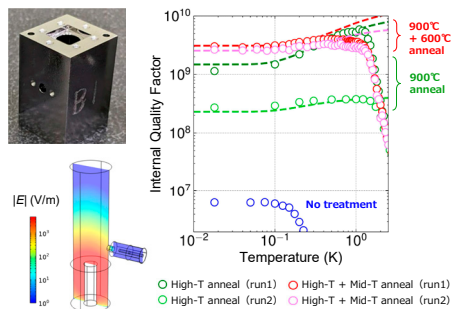


Graph-size dependence of average time to obtain target scores. We set best scores obtained with CIM as target scores.

Solving Maximum Independent Set Problems with Coherent Ising Machine

The maximum independent set (MIS) problem is a fundamental optimization problems in graph theory and related to various applications such as network design and optimal resource allocation. We explore the MIS on large-scale graphs using a coherent Ising machine (CIM), which simulates the Ising model with degenerate optical parametric oscillator pulses. For MIS instances of random graphs with 50% edge density, we compare the average time required to reach a reference solution with that of the optimized simulated annealing algorithm and confirm the superior scaling performance of the CIM.

H. Takesue, K. Inaba, T. Honjo, Y. Yamada, T. Ikuta, Y. Yonezu, T. Inagaki, T. Umeki, and R. Kasahara, *Sci. Adv.* 11, eads7223 (2025).



Top left: Photograph of a high-performance niobium cavity. Bottom left: Simulated electric-field distribution inside cavity. Right: Temperature dependence of internal quality factor, which characterizes cavity performance, before and after each treatment. Dashed lines are fits to model describing energy loss emanating from two-level-system impurities.

Record-high Performance in a 3D Cavity Optimized for Quantum Applications

Low-loss (long-lived) superconducting cavities are a promising platform for quantum memories, high-sensitivity sensing enabled by their narrow resonance linewidth, and searches for new physics, such as dark-matter detection. By adapting a heat-treatment technique originally developed for radio-frequency cavities used in particle accelerators, we achieve an internal quality factor in a 3D niobium cavity of 3×10^9 which is more than twice the previously reported highest value. Despite the large difference in the electric-field strength between accelerator cavities and quantum cavities, the observation that the same treatment improves performance in both cases suggests a common physical origin of the energy losses.

T. Takenaka, I. Mahboob, S. Saito, T. Kubo, and T. Saeki, 22nd International Conference on RF Superconductivity (SRF2025), MOP81 (2025).

$$\text{BH equation : } S(B) = \frac{kc^3 A_B}{4\hbar G}$$



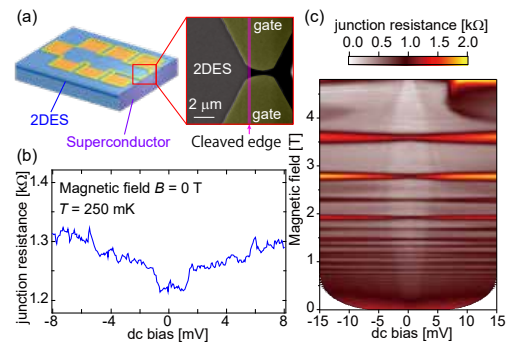
$$\text{Proposal: } I(\bar{B})B^+ = \frac{kc^3 A_B}{4\hbar G}$$

BH equation and proposed equation. In BH equation, surface area A_B of black hole B is proportional to black hole's entropy $S(B)$. In the proposed equation, surface area A_B is proportional to coherent information $I(\bar{B})B^+$ shared between exterior \bar{B} and positive-energy particles B^+ inside hole.

Do Black Holes Store Negative Entropy?

The Bekenstein-Hawking (BH) equation argues that a black hole has entropy proportional to its surface area. However, this equation gives rise to a contradiction among general relativity, quantum mechanics, and Hawking's pair-creation picture that produces thermal radiation from a black hole. To resolve this contradiction, we proposed a modified version of the BH equation. In this revised equation, the black hole's area is taken to be proportional not to simple entropy but to "coherent information," which can only be interpreted as quantum entanglement. Our equation suggests that negative-energy particles inside a black hole behave as if they have "negative" entropy.

K. Azuma, S. Subramanian, and G. Kato, *Prog. Theor. Exp. Phys.* 2025, 053A01 (2025).



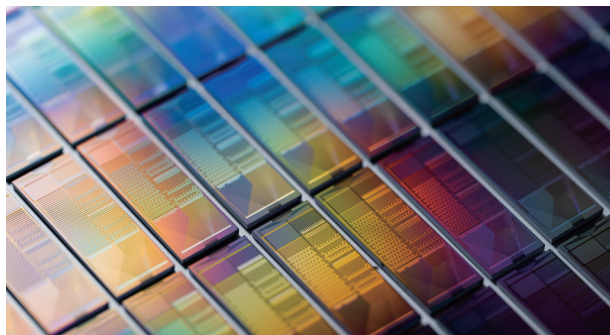
(a) Schematic illustration of cleaved-edge overgrowth device and electron micrograph of junction at substrate edge. (b) and (c) Andreev reflection (b) at zero and (c) high magnetic fields. Dips near zero bias indicate enhancement of conductance due to Andreev reflection.

Andreev Reflection in Quantum Hall Regime Using Cleaved-edge Overgrowth

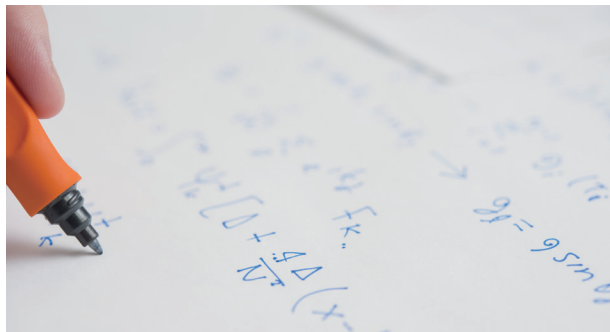
At the interface between a superconductor and quantum Hall system, theory predicts the emergence of novel quasiparticles that are distinct from conventional fermions and bosons, with potential applications to fault-tolerant quantum computation. However, achieving such coupling is challenging, because superconductivity is suppressed by strong magnetic fields, whereas the quantum Hall effect requires them. To overcome this issue, we used cleaved-edge overgrowth, in which a superconductor is deposited on the cleaved edge surface of a semiconductor substrate hosting a two-dimensional electron system (2DES). By measuring the bias dependence of the gate-defined junction, we observed Andreev reflection, a hallmark of superconducting junctions, over a wide magnetic-field range from zero field up to 4.8 T. These results represent a significant step toward the experimental actualization of such novel quasiparticles.

T. Akiho, H. Irie, Y. Nakazawa, S. Sasaki, N. Kumada, and K. Muraki, *Nano Lett.* 24, 14790 (2024).

Nanophotonics Center



Research Center for Theoretical Quantum Information



Bio-Medical Informatics Research 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

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

Overview

Since its establishment in July 2019, the NTT Biomedical Informatics Research Center has been promoting research and development with the mission of “Creating the Future of Healthcare through ICT,” aiming to realize precise, personalized medical care and healthcare (precision medicine) optimized for each individual. Based on NTT’s medical and health vision of “realizing bio-digital twins,” the Center brings together diverse areas of expertise—including information processing, devices, behavioral support, and biology—along with the knowledge and passion cultivated through NTT’s ICT research and development. Through these efforts, we strive to contribute to the creation of a society in which people-centered healthcare, as well as happiness derived from both mental and physical well-being, can be equally enjoyed by everyone around the world.

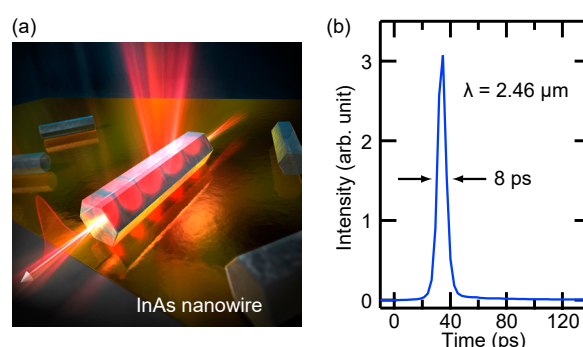
Research Themes

- Construction of cardiac bio-digital twins and elucidation of the mechanisms of heart diseases
- Monitoring of patients with heart disease through electrocardiographic measurements and prediction of heart failure, among others
- Lifestyle disease management aimed at balancing diet, work, and health
- On-chip biological models for elucidating biological functions

Ultrafast Mid-infrared Stimulated Emission from InAs Nanowires

Indium arsenide (InAs) nanowire lasers emitting in the mid-infrared region are promising nanoscale light sources for sensing applications. We successfully grew high-quality InAs nanowires and observed ultrafast stimulated emission on the picosecond scale from optically excited InAs nanowires by using our time-resolved mid-infrared photoluminescence spectroscopy system that is based on a wavelength-conversion technique. This achievement reveals the emission dynamics of mid-infrared lasers, which had previously been difficult to measure, and paves the way for developing new mid-infrared light sources based on semiconductor nanomaterials.

H. Sumikura, G. Zhang, M. Takiguchi, A. Shinya, H. Sanada, K. Oguri, and M. Notomi, *Nano Lett.* 25, 12216 (2025).

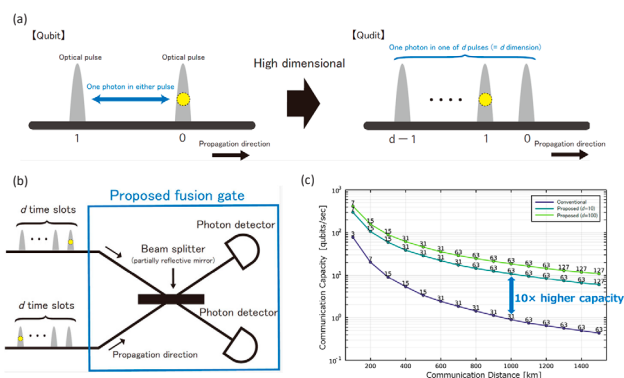


(a) Schematic of optically excited InAs nanowire. (b) Temporal evolution of emission intensity at wavelength of 2.46 μm .

Improving Success Rate of Fusion Gates with Qudits

In photonic quantum information processing, a critical operation known as the "fusion gate" has long faced a major limitation: it can succeed only 50% of the time, posing a significant barrier to practical applications. This study theoretically demonstrates that replacing conventional two-dimensional qubits with higher-dimensional qudits dramatically improves the success rate of fusion gates. As an application of this enhanced gate, we propose a long-distance quantum communication protocol and numerically show that it can achieve nearly an order of magnitude higher data capacity compared with conventional protocols.

T. Yamazaki and K. Azuma, *Phys. Rev. Lett.* (2025).

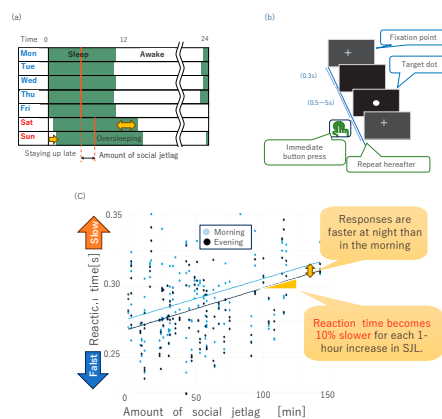


(a) Comparison between qubit and qudit using single photon. (b) Experimental setup of proposed fusion gate. (c) Comparison of quantum communication capacity vs. distance between conventional and proposed protocols.

Impact of Sleep Debt Evident in Sleep Patterns on Reaction Time

A sleep pattern known as social jetlag, in which people stay up late or oversleep on days off, is thought to indicate chronic sleep restriction (sleep debt) on weekdays. We measured participants' sleep patterns together with cognitive reaction time and inhibitory control while they went about their daily lives and examined the relationships between them. We showed for the first time that even mild social jetlag, which had previously been assumed recovered on days off, is associated with slower reaction times and reduced inhibitory control in simple cognitive tasks during everyday life. This tendency is likely because of chronic sleep restriction.

T. G. Sato, M. Takahashi, and M. Nishida, *J. Sleep Res.* e70223 (2025).



(a) Typical sleep pattern of individual with social jetlag. (b) Example of psychomotor task used (psychomotor vigilance test). (c) Results of psychomotor task. Relationship was observed whereby reaction speed became approximately 10% slower for each 1-hour increase in social jetlag.

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



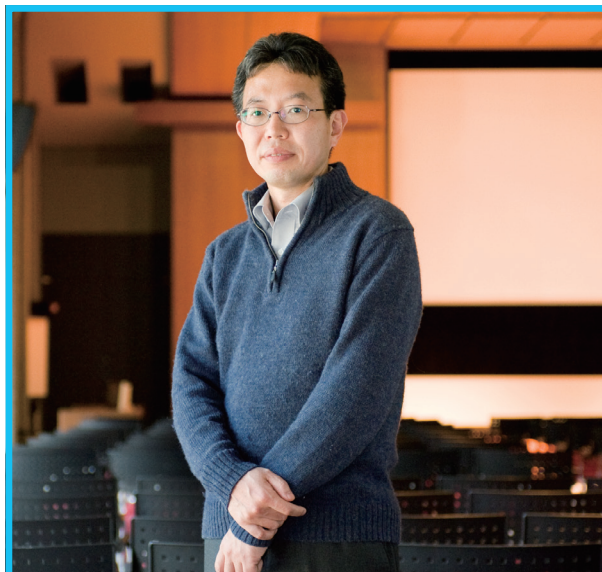
Research Subject

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



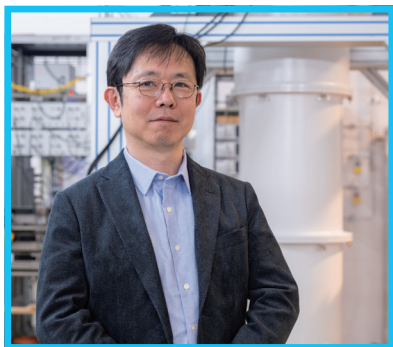
Research Subject

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.

Senior Distinguished Researcher

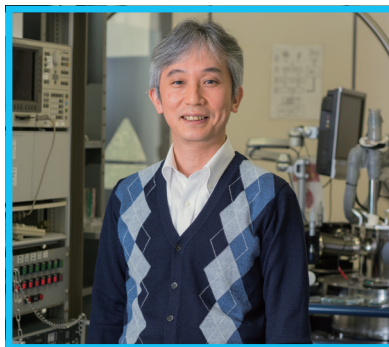
Koji Muraki



Research Subject

Electron Correlation in Semiconductor Nanostructures

Akira Fujiwara

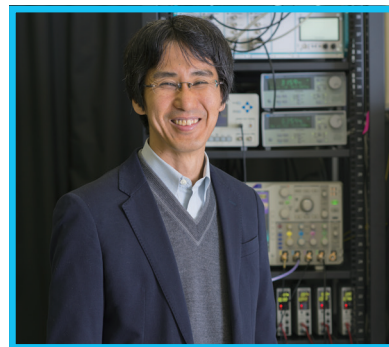


Research Subject

Ultimate Electronics Using Semiconductor Nanostructures

Hiroki Takesue

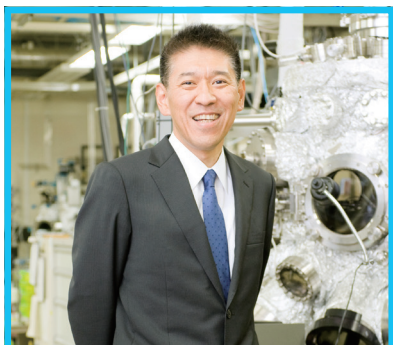
Quantum Science and Technology Laboratory
Executive Manager



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

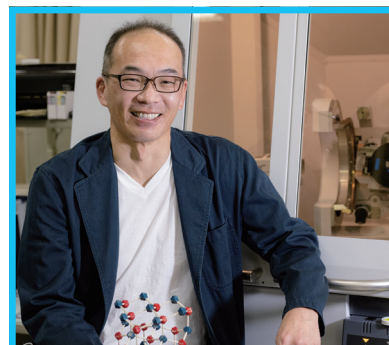


Research Subject

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

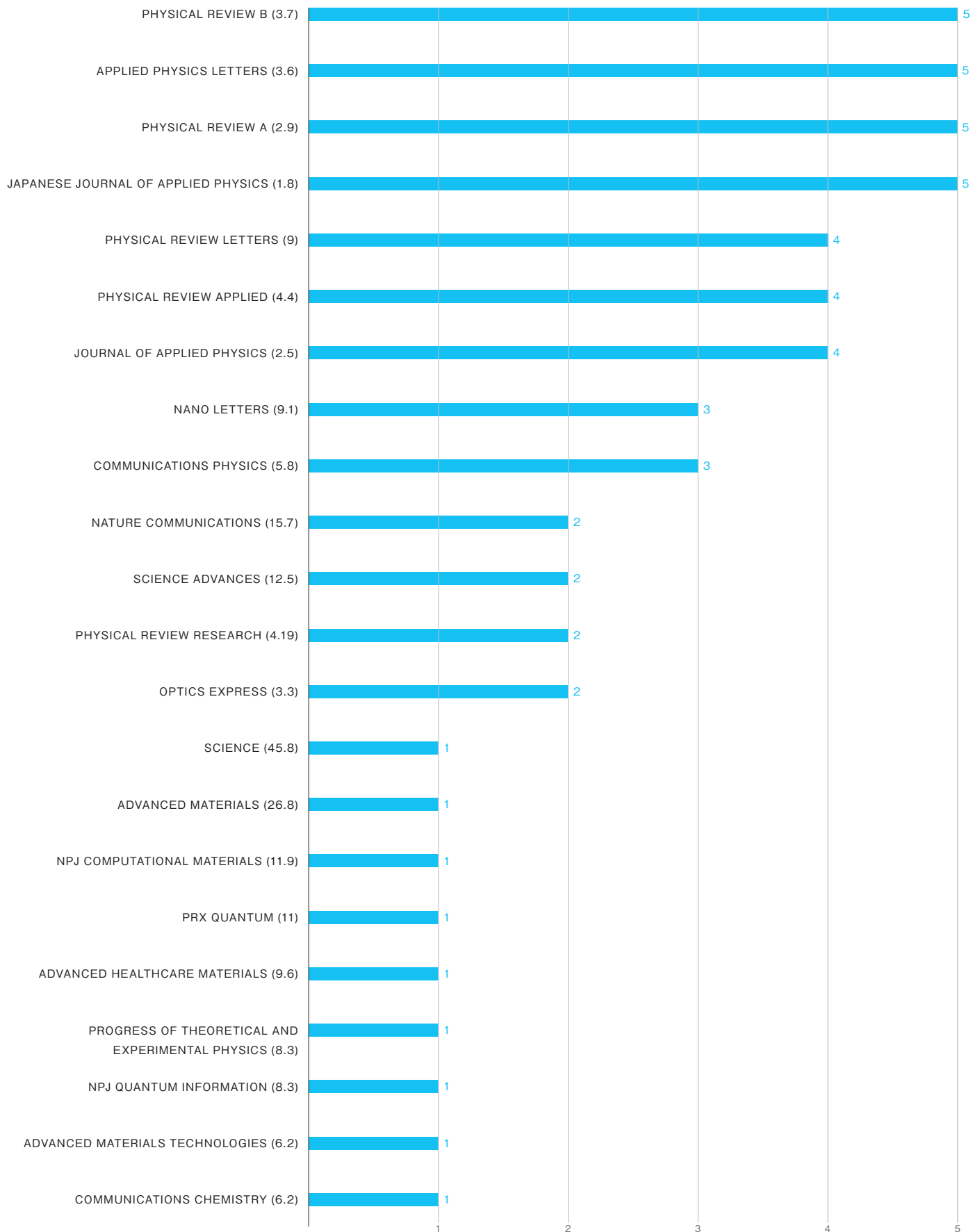
Katsuhiko Nishiguchi Haruki Sanada Koji Azuma
Hajime Okamoto Yuki Wakabayashi

Associate Distinguished Researcher

Motoki Asano Katsumasa Yoshioka

Publication List

The total number of NTT Basic Research Laboratories papers published in international journals in 2025 is 80 with an average impact factor of 5.58. The 2024 impact factor of those individual journals are shown in ().



Number of Presentations

169

(55 Invited talks)

Conferences	Numbers
Conference on Lasers and Electro-Optics 2025 (CLEO 2025)	8
SPIE Photonics West 2025	7
2025 IEEE Photonics Conference (IPC 2025)	7
Joint March Meeting and April Meeting: Global Physics Summit 2025	6
The 38th International Microprocesses and Nanotechnology Conference (MNC 2025)	6
The 16th International Conference on Recent Progress in Graphene and 2D Materials Research (RPGR 2025)	5
International Symposium on Topological Wave Science 2025	5
Frontiers of Nanomechanical Systems 2025 (FNS2025)	4
The 26th International Conference on Electronic Properties of 2D Systems & the 22nd International Conference on Modulated Semiconductor Structures	4
31st International Workshop on Oxide Electronics (IWOE 31)	4
2025 Photonics and Electromagnetics Research Symposium	4

Number of Patents

84

List of Award Winners

JSAP Outstanding Paper Award

Cavity Optomechanical Mass Sensor in Water with Sub-femtogram Resolution **Motoki Asano, Hiroshi Yamaguchi, Hajime Okamoto**

The Laser Society of Japan, Encouragement Award

Long-lived valley-polarization in Suspended WSe₂ Monolayers Strained by Electrostatic Pressure **Mariani Giacomo**

The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology of Japan, The Young Scientists' Prize

Self-Foldable Three-Dimensional Biointerfaces by Strain Engineering of Two-Dimensional Layered Materials on Polymers **Tetsuhiko Teshima**

Outstanding Research Award from Lab on a Chip

Biomorphic On-Chip Hydrogel Device Capable of Actuation in Cell Culture Conditions **Riku Takahashi, Shogo Himori, Aya Tanaka**

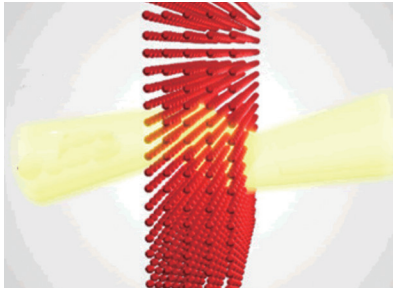
µmTCF-2025 Invited Talk Delegates Felicitiation Award

Temperature Dependent Ultrafast Edge Photocurrent in WTe₂ Probed by On-chip THz Spectroscopy **Subhashri Chatterjee**

2025 Applied Physics Letters Rising Star Collection

Self-catalyzed Vapor-liquid-solid Growth of GaS Nanobelt for Nano-optoelectronic Applications **Yukihiro Endo**

News Release

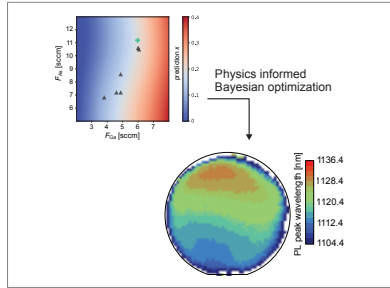


2025.2.13

A New Meta: Realizing Negative Refraction of Light Using Atomic Media

- A Novel Platform Towards Applications Such as Powerful Lenses and Cloaking Devices -

Theoretical Quantum Physics Research Group

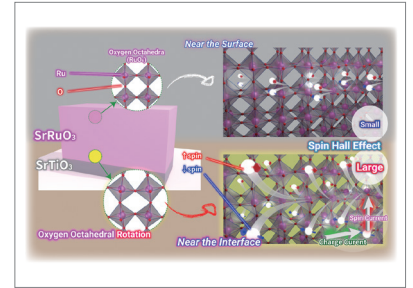


2025.05.02

Using AI to Automate Materials Analysis and Synthesis for Semiconductor Thin Films

- Contributing to more Efficient Manufacturing Operations for Optical Communications Devices -

Low-Dimensional Nanomaterials Research Group

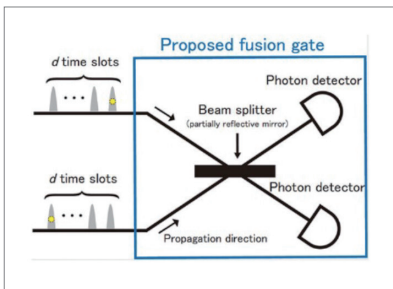


2025.05.14

Tiny Shifts of Oxygen Atoms Enable Magnetization Reversal

- Breakthrough in Highly Efficient Magnetization Switching in a Single-Layer Ferromagnetic Weyl Oxide -

Low-Dimensional Nanomaterials Research Group

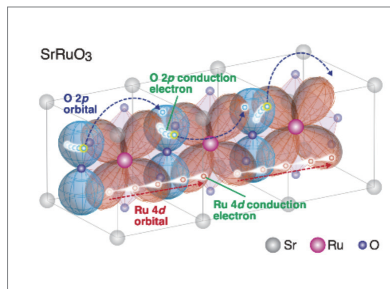


2025.05.21

Breaking the Theoretical Limit of Photonic Quantum Operation with High-Dimensional "Quantum Dits"

- A New Path Toward Earlier Realization of High-Speed, Long-Distance Quantum Communication -

Theoretical Quantum Physics Research Group

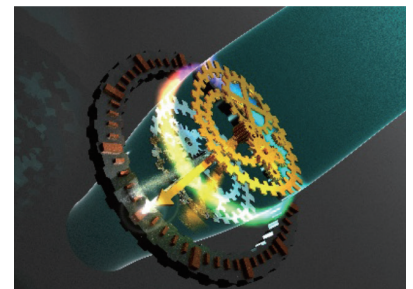


2025.07.30

World's First Discovery of New Electronic State in Functional Oxides

- A Lead for the Development of Future High-Performance Electronics Materials -

Low-Dimensional Nanomaterials Research Group

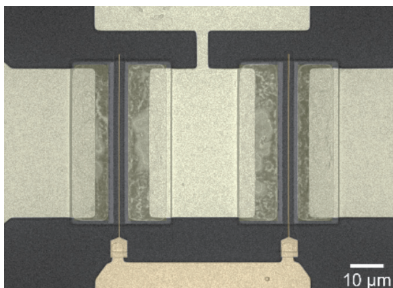


2025.09.19

World's First Success in Real-Time Optical Control of Synchronization Between Microscopic Oscillators

- Toward Next-Generation Information Technology Inspired by Brain Mechanisms -

Nanomechanics Research Group



2025.12.9

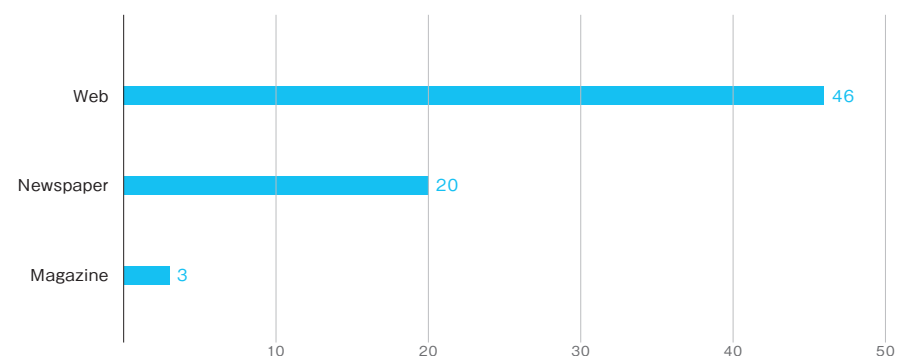
World's first AlN-based high-frequency transistor for post-5G communication

- Expanding Application Areas of AlN from Power Conversion to Wireless Communications -

Thin-Film Materials Research Group

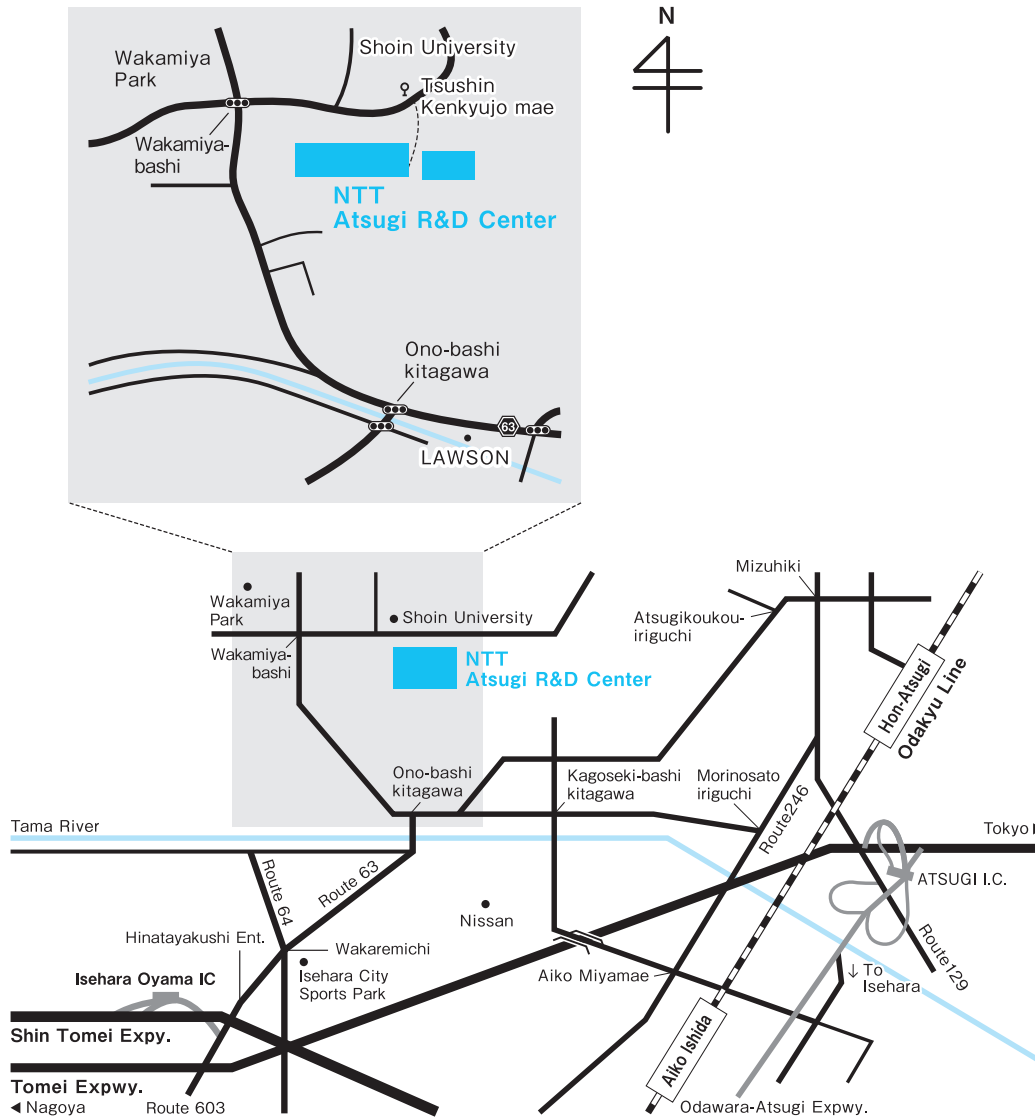
Number of News Reports

69



Basic Research Laboratories NTT, Inc.

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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.



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