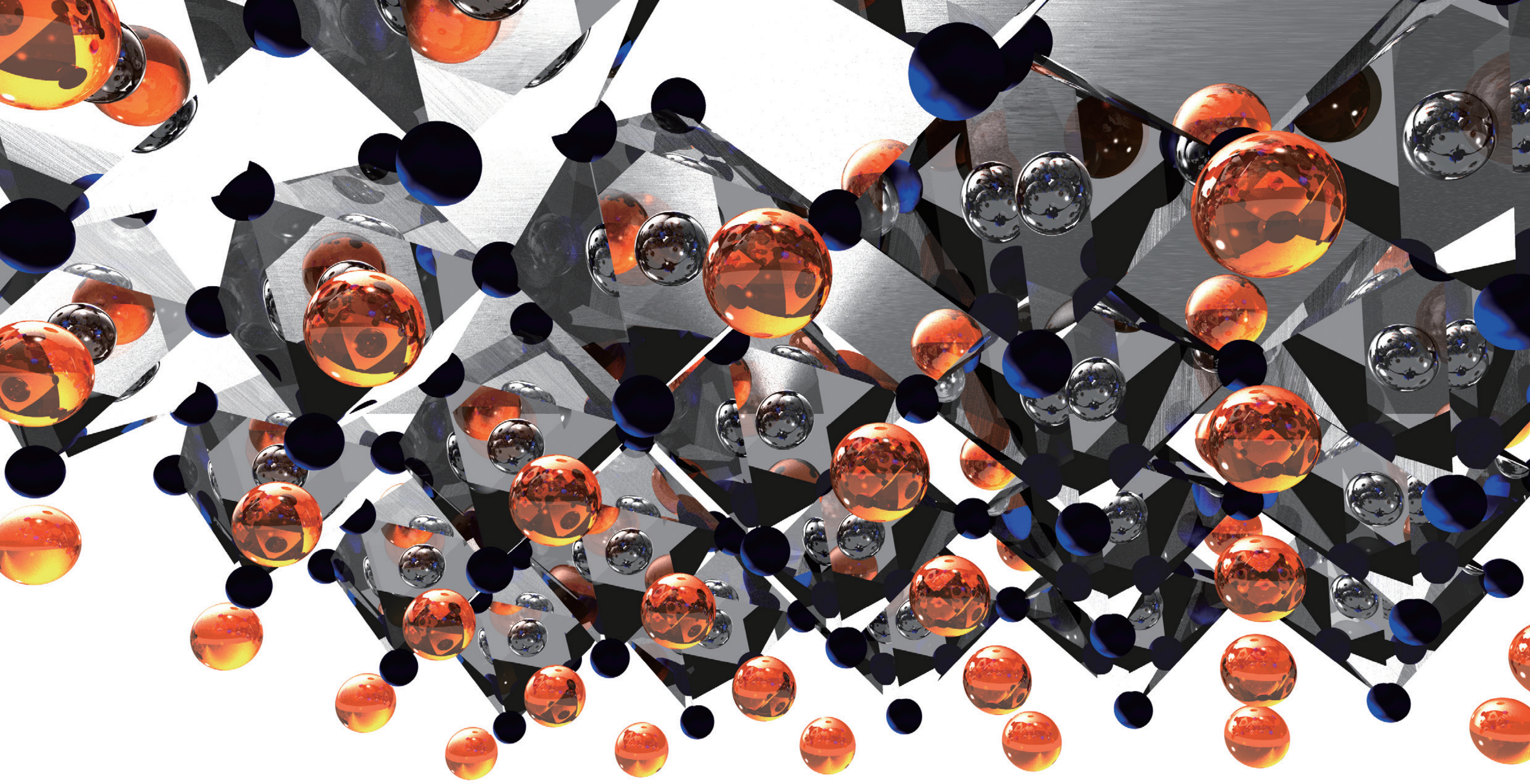


NTT Basic Research Laboratories

Annual Report 2020

NTT BASIC RESEARCH LABORATORIES

Message from the Director

We at NTT Basic Research Laboratories (BRL) are extremely grateful for your interest and support with respect to our research activities.

BRL's core mission is to promote progress in science along with innovations in cutting-edge technology to advance NTT's business. Researchers in physics, chemistry, biology, mathematics, electronics, informatics, and medicine have been undertaking groundbreaking research within the material, physical, optical, and quantum sciences fields. In 2020, we renewed our research structure to establish the Materials Design & Science, Advanced Applied Physical Science, and Quantum Science & Technology Laboratories to better reflect the current nature of BRL and its mission. This new structure brings all of our key themes together in the same place.

Our management principle has cultivated the tradition of an "open door" policy at BRL. We are collaborating with many universities and research institutes all over the world as well as within NTT. Further, we have organized a number of workshops and international symposiums (ISNTT and NTT-BRL School are two well known examples) at the Atsugi R&D Center, where we share our research results and efforts and host open discussions with people of various background and interests. Our meeting style has changed somewhat over the last year due to the COVID-19 pandemic, and under these circumstances, our management recognizes that the "open door" has never been more important to BRL. We are currently planning to organize a new style of workshops and symposiums that will be facilitated on the Internet. We will never change our core management principle.

These activities enable us to pursue our missions with respect to the promotion of advances in science and the innovation of leading-edge technology for NTT's business. Your continued support in this is greatly appreciated.

Director of NTT Basic Research Laboratories

Hideki Gotoh

Front image:

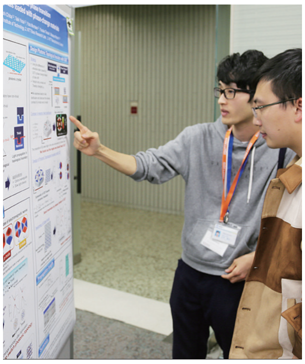
Perovskite oxides

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

Activity Report

Advisory Board

The aim of the Advisory Board is to provide an objective evaluation of our research plans and activities that will enable us to utilize strategic management in a timely manner. At this meeting, BRL researchers had lunch and a poster session with the board members, where they had the chances to present their research to the board in a casual atmosphere. The next meeting, our 11th will be held online in 2021.




ISNTT

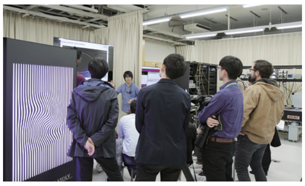
International School and Symposium on Nanoscale Transport and phoTonics

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

NTT-BRL School

NTT-BRL School is designed to foster young researchers and to promote the international visibility of NTT. In 2019, with “Quantum Hybrid Systems” as the theme, we had lectures by Prof. Göran Johansson and Prof. Per Delsing (both from Chalmers University of Technology) and by Dr. Kouichi Semba (National Institute of Communications Technology). There were also laboratory tours and a poster session.




LASOLV Seminar

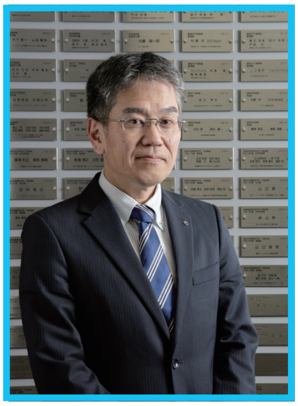
To expand the application research fields of optical oscillator-based computing, the LASOLV seminar was held in February 2020. With a total of 80 attendees, the exciting power of LASOLV was demonstrated with the combinatorial optimization problems. Moreover, Prof. Nozomu Togawa (Waseda University) made a special lecture on the emerging approaches around the world for solving combinatorial optimization problems with the non von Neumann architecture.

Organization

NTT Basic Research Laboratories

Director

Hideki Gotoh



Research Planning Section

Executive Manager

Kazuhide Kumakura

Multidisciplinary Materials Design and Science Laboratory

Executive Manager

Hideki Yamamoto

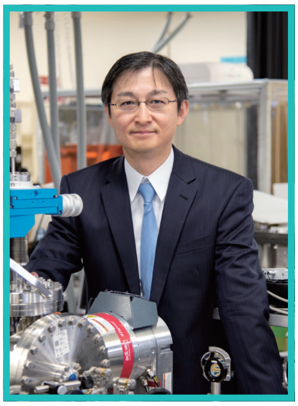
P5

- 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 (13)
- Research Associate/Specialist…10
- Joint Researcher…7
- International Interns…7*
- Domestic Interns…9*
- Guest Researchers…1*

*…Jan. to Dec. 2020 total

As of Dec. 31, 2020

10th Advisory Board Meeting (January 30, 2019)

Advisory Board

Forschungszentrum Jülich, Germany
Prof. Andreas Offenhäusser

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

Chalmers University of Technology, Sweden
Prof. Per Delsing

Laboratoire Kastler Brossel, France
Sorbonne Université, Ecole Normale Supérieure, CNRS
Prof. Elisabeth Giacobino

CEA Saclay, France
Prof. Christian Glattli

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

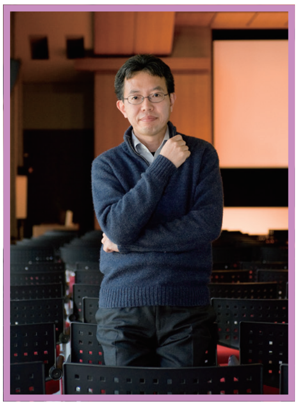
University of Illinois at Urbana-Champaign, U.S.A.
Prof. Sir Anthony J. Leggett

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

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

Nanophotonics Center

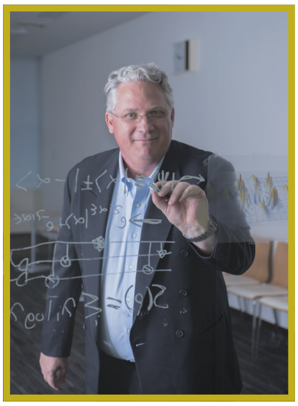
Project Manager
Masaya Notomi



P11

Research Center for Theoretical Quantum Physics

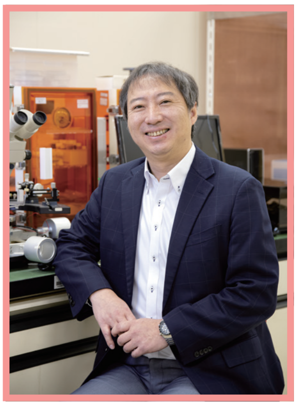
Project Manager
William John Munro



P11

Bio-Medical Informatics Research Center

Project Manager
Hiroshi Nakashima



P11

Research Professors

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

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

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).

Group Introduction

Thin-Film Materials Research Group

Novel Semiconductor Devices

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

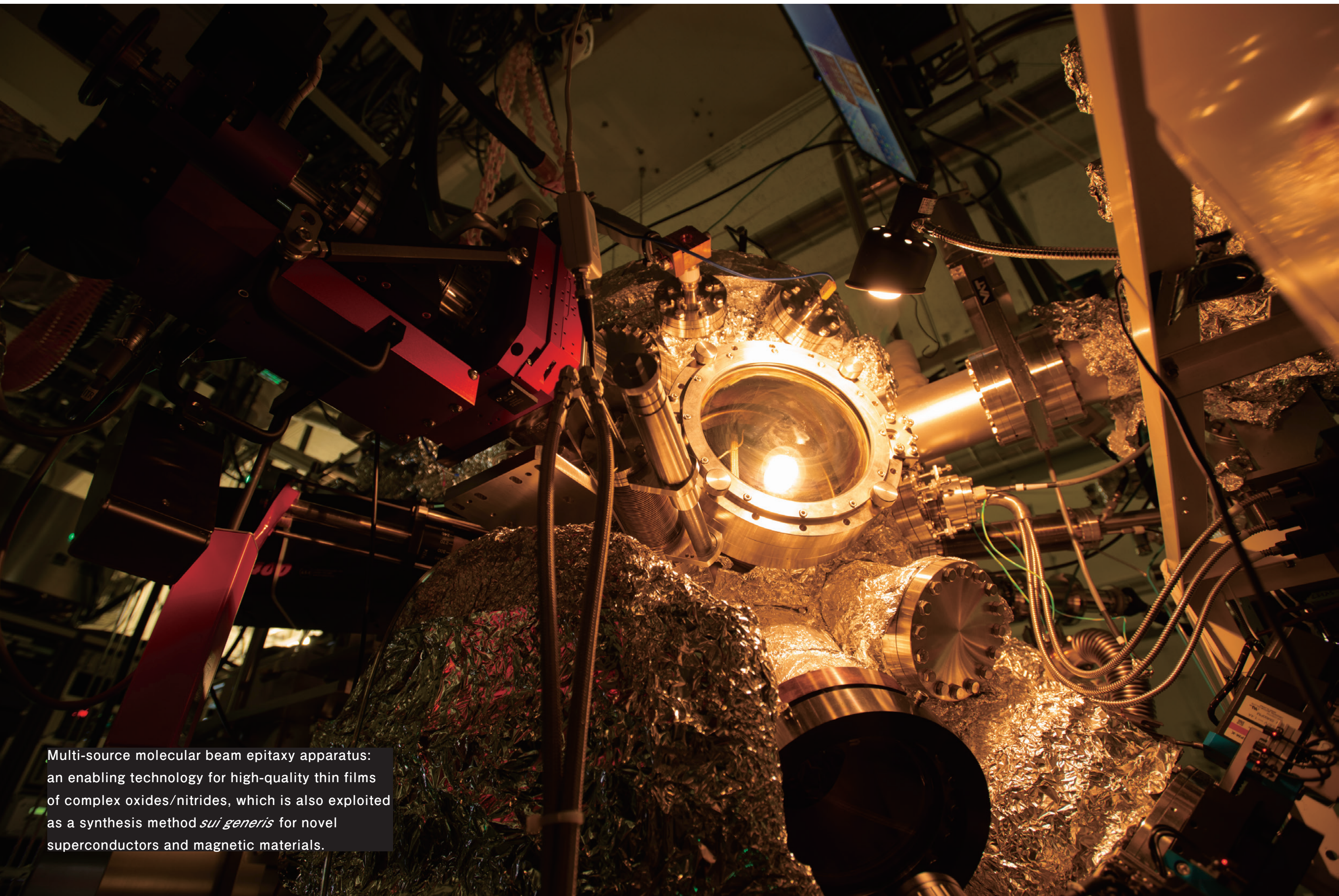
Molecular and Bio Science Research Group

Biocompatible Electrode Materials

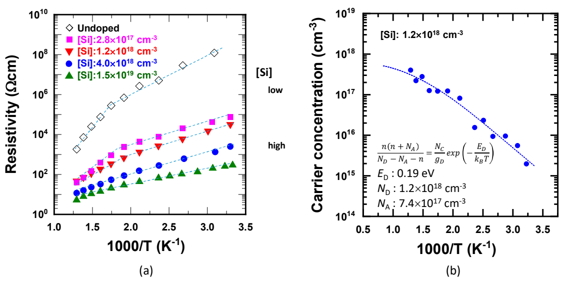
Development and application of bioelectrode materials for measurement of deep biological information

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.

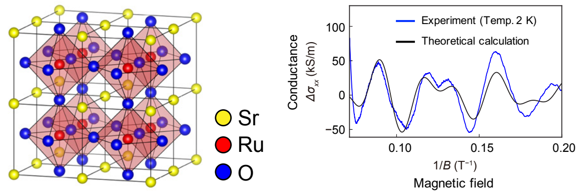


(a) Temperature dependence of resistivity for undoped and Si-doped c-BN (001) layers.
(b) Temperature dependence of carrier concentration for Si-doped c-BN (001) layer ([Si] = 1.2×10^{18} cm^{-3}).

n-type Electrical-conductivity Control for Cubic Boron Nitride (c-BN) Epitaxial Layers

Cubic BN (c-BN) is a widegap semiconductor with excellent material properties such as large breakdown field and high thermal conductivity, etc. For c-BN, the Baliga figure-of-merit, which indicates the expected performance limit for power switching devices, is larger than those of AIN and diamond. For electron device applications of c-BN, electrical conductivity control by impurity doping is necessary. Recently, we achieved control of the n-type conductivity of c-BN epitaxial layers with Si doping: the resistivity decreases when the Si concentration is increased. This result will open the door for new power device applications of c-BN

K. Hirama, Y. Taniyasu, H. Yamamoto, and K. Kumakura, Appl. Phys. Lett. 116, 162104 (2020).

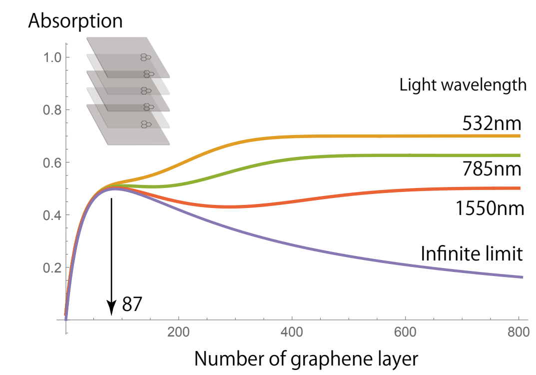


(Left) Crystal structure of $SrRuO_3$.
(Right) Quantum oscillations stemming from the Weyl semimetal states in $SrRuO_3$. The experimental result (blue line) coincides well with the theoretical calculation (black line).

Emergence of Magnetic Weyl Semimetal State in Ultrahigh-quality $SrRuO_3$ Thin Films

$SrRuO_3$, a ferromagnetic metal, is an essential material for oxide electronics and spintronics. We observed quantum transport phenomena peculiar to a unique electronic state called “magnetic Weyl semimetal” in ultrahigh-quality $SrRuO_3$ thin films, which were achieved by a machine learning-assisted thin film growth technique. This first experimental proof of the magnetic Weyl semimetal state in oxide materials will lead us to innovative oxide materials and novel quantum devices in the future.

Y. K. Wakabayashi, et. al., APL Mater. 7, 101114 (2019).
K. Takiguchi, Y. K. Wakabayashi, et. al., Nat. Commun. 11, 4969 (2020).

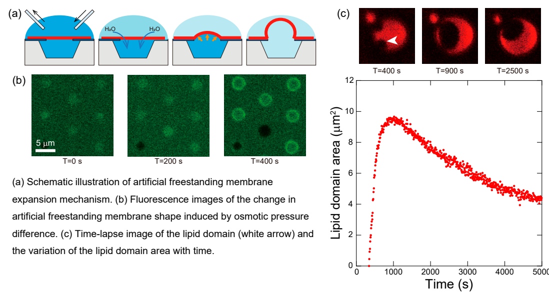


Calculated results

Universal layer number distinguishing between graphene and graphite

Graphene absorbs light in accordance with the fine-structure constant $\alpha \cong 1/137$: e.g., about 2.3 % of visible light is absorbed by graphene. The α value is universal in the sense that it is not related to material parameters but rather is solely related to the elementary charge, which is a fundamental constant governing the coupling of light and matter. We found in graphite a new universality governed only by α in which the reciprocal of α appears as a characteristic number of layers, $2/\pi\alpha \approx 87$, in the light absorptance of an N-layer graphene.

K. Sasaki and K. Hitachi, Commun. Phys. 3, 90 (2020).
K. Sasaki. J. Phys. Soc. Japan 89, 094706 (2020).



(a) Schematic illustration of artificial freestanding membrane expansion mechanism. (b) Fluorescence images of the change in artificial freestanding membrane shape induced by osmotic pressure difference. (c) Time-lapse image of the lipid domain (white arrow) and the variation of the lipid domain area with time.

Control of Lipid Domain Formation in Artificial Membranes

The lipid domain in biological cell membranes plays a very important role in signal transduction. We developed a method to form a model structure of the lipid domain in an artificial freestanding membrane formed on a microwell-patterned substrate. We succeeded in forming a stable domain for more than 1 hour by deforming the artificial freestanding membrane through the osmotic pressure difference inside and outside the well and moving the lipid and cholesterol necessary for domain formation to the well part. Our accomplishment of forming and controlling domain structures in artificial membranes is expected to serve as a key technology for understanding biological phenomena.

A. Oshima, H. Nakashima, and K. Sumitomo, Jpn. J. Appl. Phys. 59, 027001 (2020).

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.

Group Introduction

Nanodevice Research Group

Single-electron Devices for Ultimate Electronics

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

Nanodevices with Novel Functions

Novel and high performance nanodevices based on silicon and hybrid materials

Nanomechanics Research Group

Semiconductor Opto/electromechanics

Novel devices using mechanical functionality in semiconductor fine structures

Phonon Manipulation

Propagation control of acoustic waves using artificial structures

Quantum Optical Physics Research Group

Manipulation of Ultrafast and Ultra-stable Laser Field

Explore ultrafast physics and establish the standard optical frequency

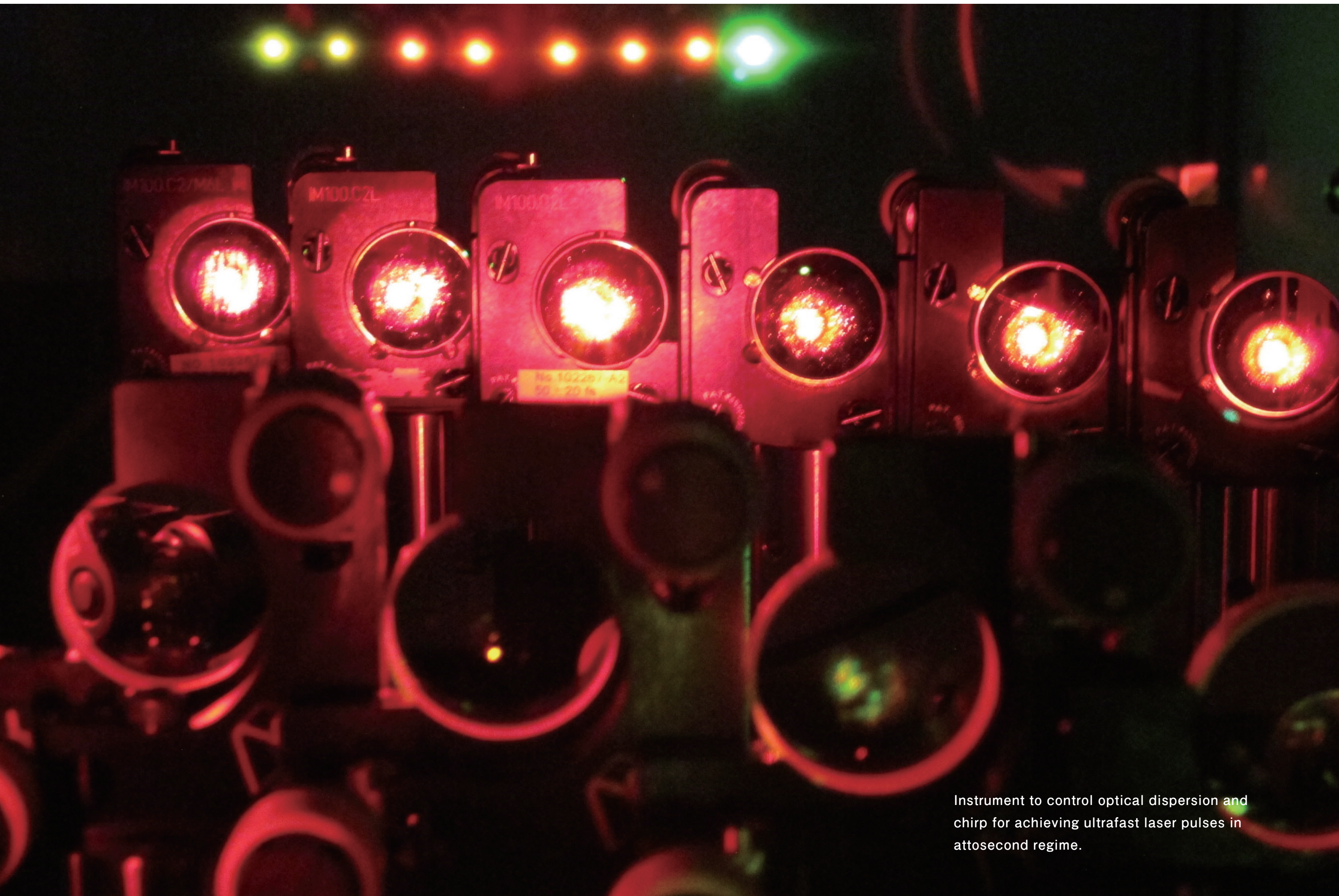
Nano-scale Physics in Optically-active Materials

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

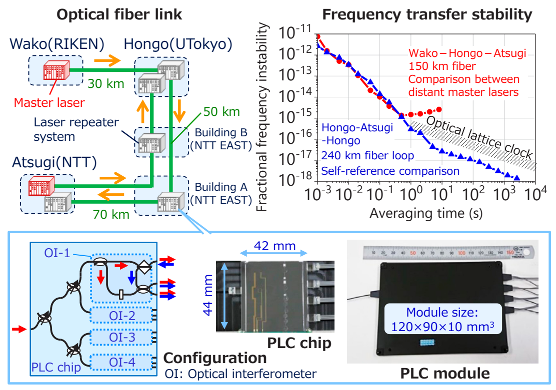
Photonic Nano-Structure Research Group

Integrated Nanophotonics Technologies

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



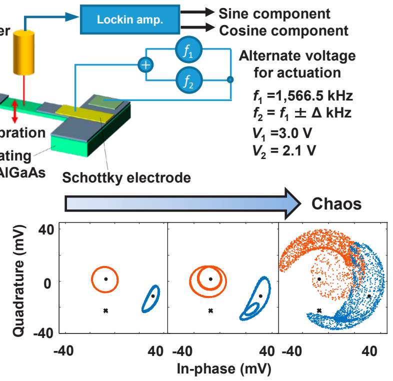
Instrument to control optical dispersion and chirp for achieving ultrafast laser pulses in attosecond regime.



Optical Frequency Distribution Using Laser Repeater Stations with Planar Lightwave Circuits

We have been conducting research on ultra-high-precision optical frequency transfer via telecom fiber networks with the aim of achieving time and frequency synchronization with accuracy exceeding GNSS and observing relativistic effects using optical clock networks. We have developed the world's first ultra-low-noise laser repeater systems based on a planar lightwave circuit in collaboration with NTT Device Technology Laboratories. We installed the systems in a commercial telecom fiber network of NTT East, which connects RIKEN, the University of Tokyo (UTokyo), and NTT, and demonstrated optical frequency transfer over a 200-km fiber with accuracy exceeding that of optical lattice clocks.

T. Akatsuka, T. Goh, H. Imai, K. Oguri, A. Ishizawa, I. Ushijima, N. Ohmae, M. Takamoto, H. Katori, T. Hashimoto, H. Gotoh, and T. Sogawa, Opt. Express 28, 9186 (2020).

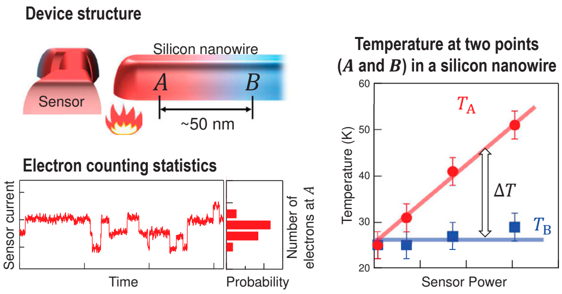


Schematic illustration of the device and the measurement setup that allows the chaos generation (top) and the experimental data (right).

Demonstration of a Novel Scheme to Generate Chaotic Signals Using a MEMS Oscillator

Recently, there has been increasing interest in applying chaotic signals in the field of information technologies, such as machine learning and secure communications. With such applications, the efficient generation of chaotic signals using on-chip devices takes on an added importance. Microelectromechanical systems (MEMS) oscillators are one of the promising candidates that could meet such requirements, as they have advantages of high integration capability and precise electrical control. We succeeded in generating chaotic signals using a MEMS oscillator with lower voltage than typically reported in literature. This new method enables the integration of chaos generators with standard MEMS devices and allows machine learning of the output data from these devices directly on a common semiconductor chip.

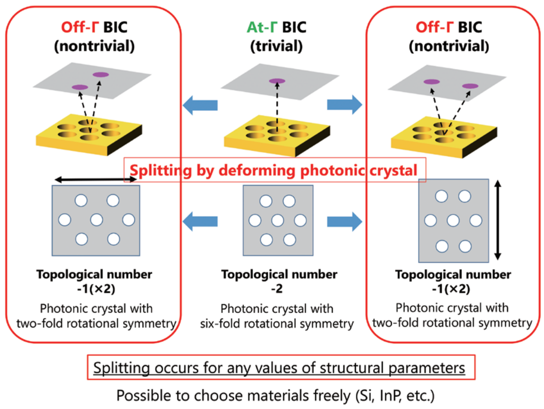
S. Houri, M. Asano, H. Yamaguchi, N. Yoshimura, Y. Koike, and L. Minati, Phys. Rev. Lett. 125, 174301 (2020).



Observation of Thermoelectric Effect in a Silicon Nanowire MOSFET by Using Single-electron Counting Statistics

We investigated nanometer-scale non-equilibrium phenomena in silicon single-electron devices by observing the Seebeck effect in a silicon nanowire using electron counting statistics. The stochastic nature of the electron provides us with information on the temperature difference between two points with ten-nanometer separation in a silicon nanowire.

K. Chida, A. Fujiwara, and K. Nishiguchi, 33rd International Microprocesses and Nanotechnology Conference (MNC 2020).



Generation and Annihilation of Topologically Protected Bound States in the Continuum and Circularly Polarized States by Symmetry Breaking

Recently, the topological phenomena of photons in photonic crystals have been extensively investigated. A bound state in the continuum (BIC), which is one of the topological singularities in photonic crystals, is a unique topological state of photons in photonic crystals. However, we must carefully tune the structural parameters of photonic crystals in order to generate nontrivial BICs. We have found a scheme to deterministically generate nontrivial BICs by deforming a photonic crystal and lowering its symmetry. This enables us to control topological singularities dynamically and create novel light-emitting devices with topological singularities.

T. Yoda and M. Notomi, Phys. Rev. Lett. 125, 053902 (2020).

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.

Group Introduction

Quantum Optical State Control Research Group

Photonic Quantum Communication

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

Non-von Neumann Computation Using Quantum Optics

New computers based on coupled optical oscillators

Theoretical Quantum Physics Research Group

Theoretical Quantum Information Science

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

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

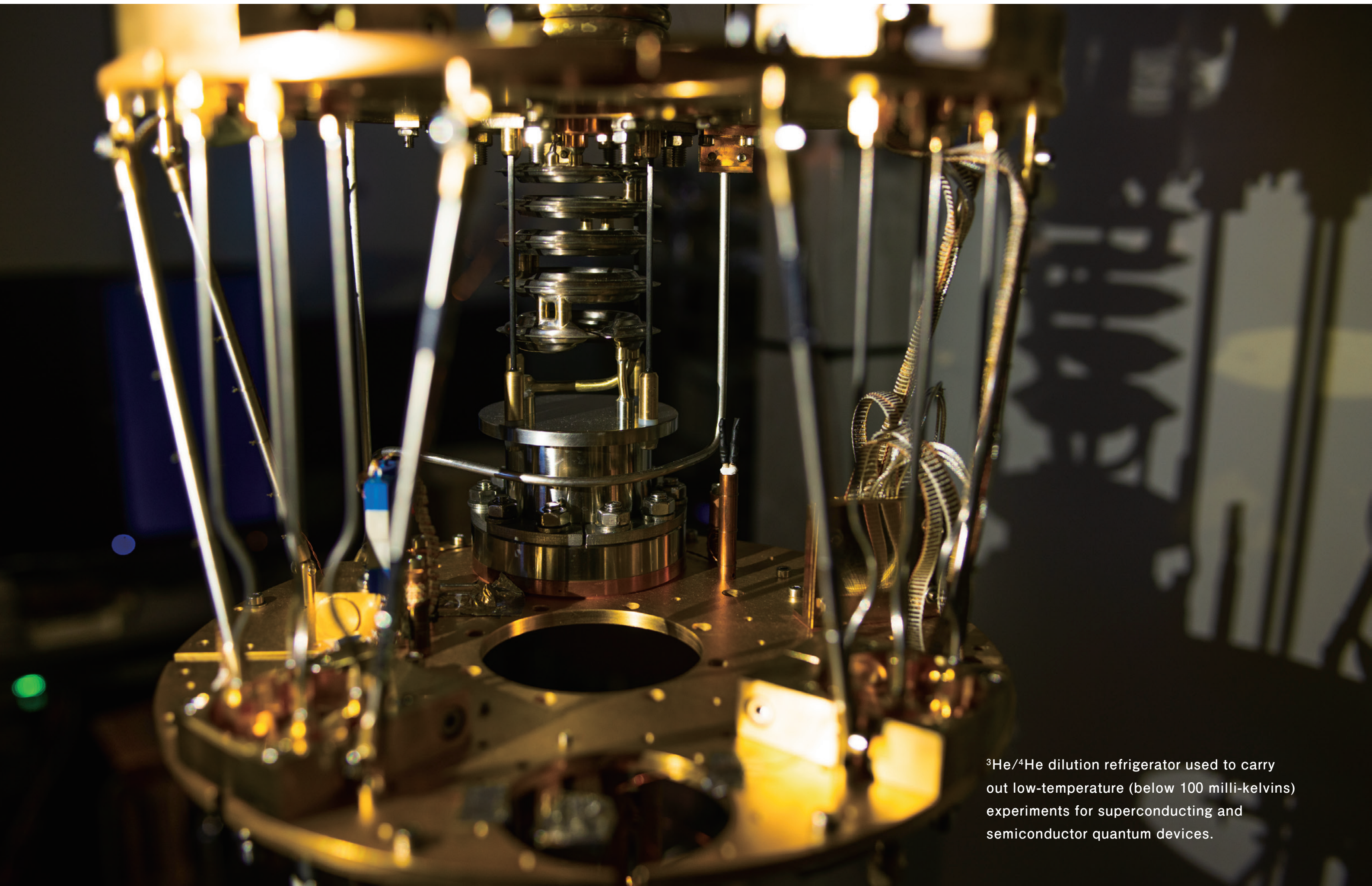
Quantum Solid State Physics Group

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

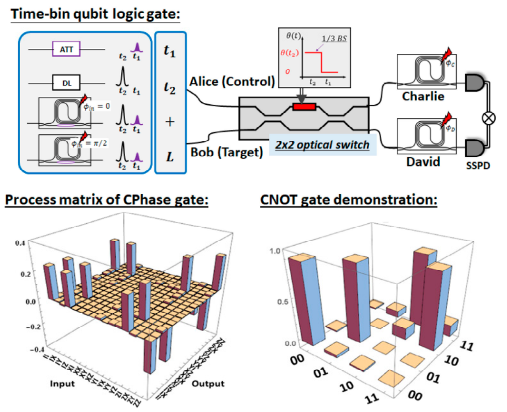
Unconventional charge and spin transport phenomena in quantum devices

Fast Coherent Carrier Dynamics in Electronic Devices

Information processing with coherent electron motion



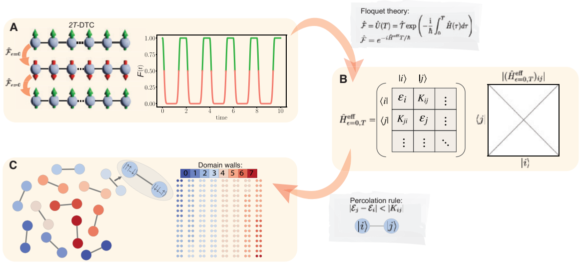
$^{3}He/^{4}He$ dilution refrigerator used to carry out low-temperature (below 100 milli-kelvins) experiments for superconducting and semiconductor quantum devices.



Controlled-phase Gate for Time-bin Qubits

Time-bin qubits, which encode the quantum information on a superposition of single photon states in two different time slots, have been implemented in quantum communication over optical fiber. However, two-qubit quantum gates for time-bin qubits have not yet been achieved. We demonstrated the first controlled-phase (CPhase) gate for time-bin qubits using a 2 × 2 optical switch as a beam splitter with a splitting ratio that changes depending on the temporal modes. This technology will be useful for achieving advanced quantum information processing over optical fiber networks.

H. P. Lo, T. Ikuta, N. Matsuda, T. Honjo, and H. Takesue, Appl. Phys. Express,11, 092801 (2018), (Spotlights 2018).
H. P. Lo, T. Ikuta, N. Matsuda, T. Honjo, W. J. Munro, and H. Takesue, Phys. Rev. Applied 13, 034013 (2020).

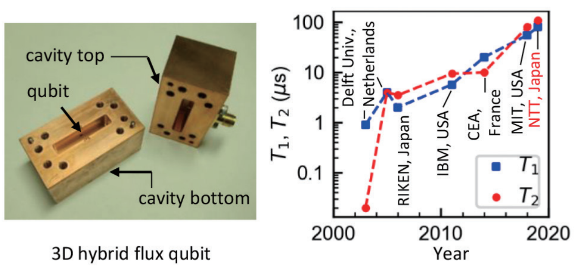


(A) Shows the 2T-DTC dynamics with no rotation error.
(B) Shows the effective Hamiltonian represented as a tight-binding matrix.
(C) After applying the percolation rule, the effective Hamiltonian is represented as a graph.

Simulating Complex Quantum Networks with Time Crystals

Crystals are widely present in everyday life in the form of solid materials with atoms arranged in regular patterns, such as salt and diamonds. Crystalline structures also appear in time and are known as discrete time crystals. By using common tools in graph theory, we here introduce a method to describe and characterize the physical phenomena related to discrete time crystals. During their melting process, we show the emergence of a preferential attachment mechanism that is directly associated with the existence of scale-free networks. Our work opens a new avenue of research and the possibility to use discrete time crystals as quantum simulators of complex quantum networks.

M. P. Estarellas, T. Osada, V. M. Bastidas, B. Renoust, K. Sanaka, W. J. Munro, and K. Nemoto, Sci. Adv 6, eaay8892 (2020).



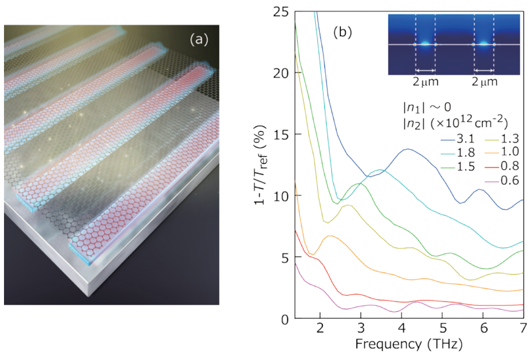
3D hybrid flux qubit

Evolution of relaxation times in flux qubits

Long-lived 3D Hybrid Flux Qubits

We developed a hybrid superconducting qubit that consists of a 2D capacitively shunted flux qubit embedded in a 3D microwave cavity. The hybrid qubit demonstrates excellent relaxation times that are comparable to or exceed the values reported for other types of flux qubits. Such long-lived flux-tunable qubits have potential applications in various quantum technologies, including quantum sensing and quantum computing. As one possible application, we demonstrated that a 3D hybrid flux qubit driven by a spin-locking pulse sequence can be used for the detection of high-frequency solid-state defects, which cause the qubit relaxation.

L. V. Abdurakhimov, I. Mahboob, H. Toida, K. Kakuyanagi, Y. Matsuzaki, and S. Saito, Phys. Rev. B 102, 100502(R) (2020).



(a) Formation of plasmonic cavities by spatial control of graphene carrier density.
(b) Modulation of plasmon frequency in cavities defined by electrical boundaries.

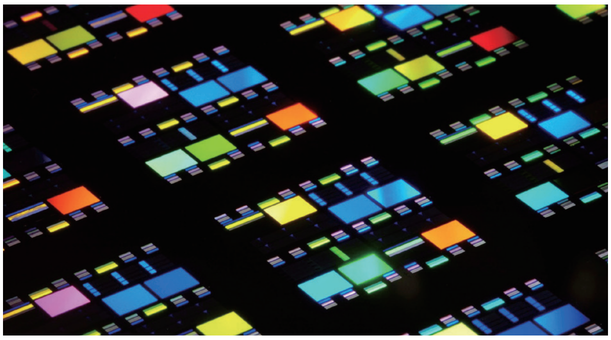
Active Spatial Control of Terahertz Plasmons in Graphene

Plasmons, which are collective charge oscillations, are useful for developing nanophotonics and metamaterials. Graphene plasmons have advantages over commonly used metal surface plasmons in terms of their electrical tunability. In this work, we developed a way to control plasmon reflectivity at electronic boundaries. This enables plasmons to be confined to desired regions with controlled confinement strength. Our device structure shows good potential for use as a platform for implementing programmable plasmonic circuits.

N. H. Tu, K. Yoshioka, S. Sasaki, M. Takamura, K. Muraki, and N. Kumada, Commun. Mater. 1, 7 (2020).

Nanophotonics Center

Nanophotonics Center



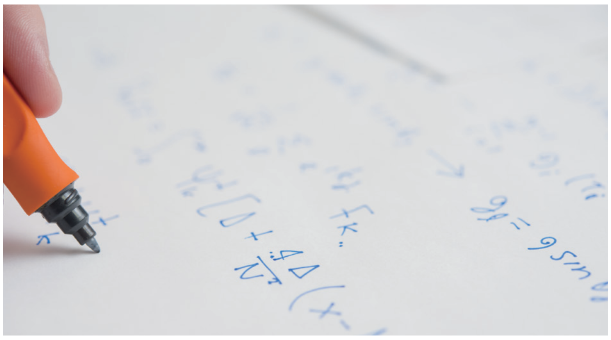
Overview

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

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

Research Center for Theoretical Quantum Physics

Research Center for Theoretical Quantum Physics



Overview

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

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

Bio-Medical Informatics Research Center

Bio-Medical Informatics Research Center

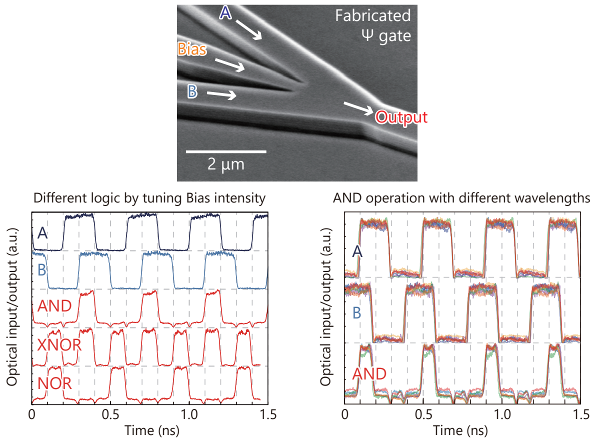
Overview

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

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

Demonstration of a High-performance Optical Logic Gate for Ultralow-latency Processing

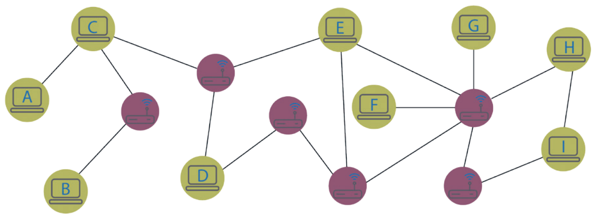
As a key device for ultralow-latency processing, we have demonstrated the high-performance operation of a 3 μm-long photonic logic gate, "Ψ (psai) gate", for the first time. The gate delay is only ~30 fs, which is 300 times shorter than a conventional electronic gate. By introducing "bias light", the function of the logic operations can be switched between AND/XNOR/NOR etc. Plus, it is wavelength insensitive, which means it can simultaneously perform different logic operations for different wavelength channels in a single gate. We believe this concept of Ψ gates is indispensable for achieving low-latency and low-energy consumption data processing based on photo-electronic converged processors.



S. Kita, K. Nozaki, K. Takata, A. Shinya, and M. Notomi, Commun. Phys. 3, 33 (2020).

Linear Programs for Entanglement and Key Distribution in the Quantum Internet

A quantum internet will enable the implementation of communication tasks beyond the reach of conventional communication networks. A pressing and necessary issue for the design of quantum network protocols is the quantification of the rates at which these tasks can be performed. In this work, we present a simple recipe that yields efficiently computable lower and upper bounds on the maximum achievable rates. This recipe is applied to protocols to distribute secret key or maximal entanglement among clients in a quantum network. Our recipe reduces the computation to a linear programming problem, and thus it can form the basis to rapidly respond to requests from such clients.



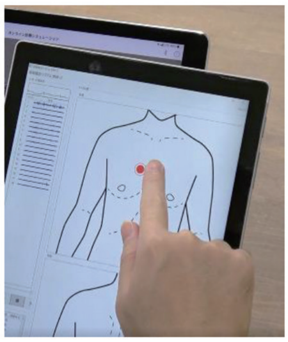
Schematic of a quantum internet.

S. Bäuml, K. Azuma, G. Kato, and D. Elkouss, Commun. Phys. 3, 55 (2020).

Wearable Acoustic Sensor Array System Featuring Remote Transmission of Body Sounds

As a basic research toward providing a person with an enhanced sense of well-being, such as early detection of diseases, we developed a wearable acoustic sensor array system that can collect sounds from various parts of the human body and send the signals remotely to a receiver terminal, which is equipped with many (e.g., 18) acoustic sensors inside an examination vest. When the system comes into practical use for medical care, a medical practitioner will be able to listen to sounds from various locations on the patient's body without having to make direct physical contact with the patient or use a traditional stethoscope, which will be useful in online medical examinations. This system is expected to play a [key] role, potentially in combination with EEG signals, in the research and development of new medical techniques such as the visualization of physical states based on 3D body sounds.

Examination vest



Specifying the positions of a virtual chest piece on a receiver terminal

M. Nakano, R. Shibue, K. Kashino, S. Tsukada, and H. Tomoike, EUSIPCO 2020, pp.1452-1456 (2020).

NTT Fellow

Shingo Tsukada

Medicine, Physiology, Biomedical interface & data analysis

Research Subject

Biological Information Elucidation Using Advanced Medical Materials

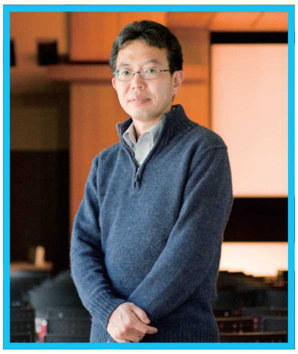
The title of "NTT Fellow" is reserved for our most gifted scientist and engineers whose research and development activities have brought them significant distinction both within NTT and internationally. Our "Fellows" are extremely highly regarded. Next the title of "Senior Distinguished Researcher" is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

December 31, 2020

Senior Distinguished Researcher

Masaya Notomi

Nanophotonics Center Project Manager



Research Subject

Photon Manipulation in Photonic Nanostructures

Hiroshi Yamaguchi

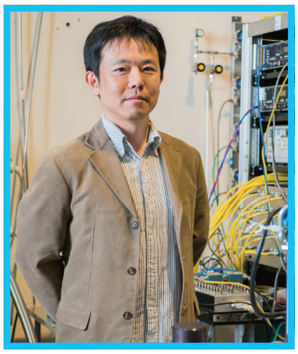
Quantum and Nano Device Research

Research Subject

Nano-mechanics in Semiconductors

Koji Muraki

Quantum Solid State Physics Research Group Leader

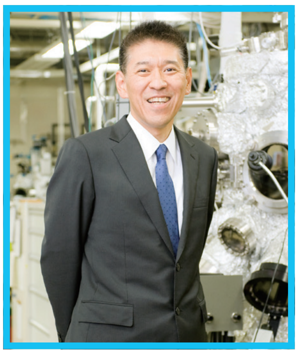


Research Subject

Electron Correlation in Semiconductor Nanostructures

Hideki Yamamoto

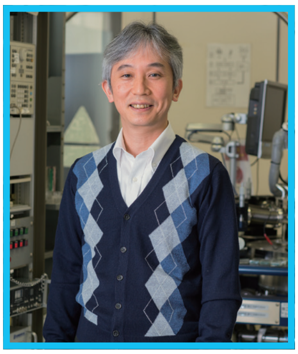
Multidisciplinary Materials Design and Science Laboratory Executive Manager



Research Subject

Design and thin-film synthesis of novel superconductors and magnetic materials with elucidation of the underlying physics

Akira Fujiwara

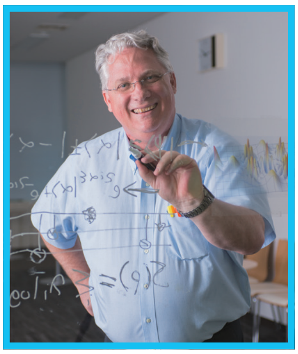


Research Subject

Ultimate Electronics Using Semiconductor Nanostructures

William John Munro

Research Center for Theoretical Quantum Physics Project Manager

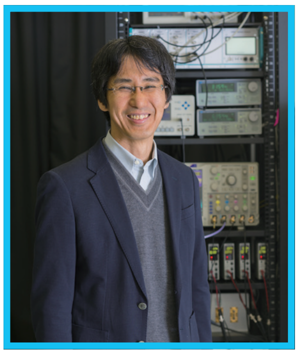


Research Subject

The Design of Quantum Technologies

Hiroki Takesue

Quantum Science and Technology Laboratory Executive Manager



Research Subject

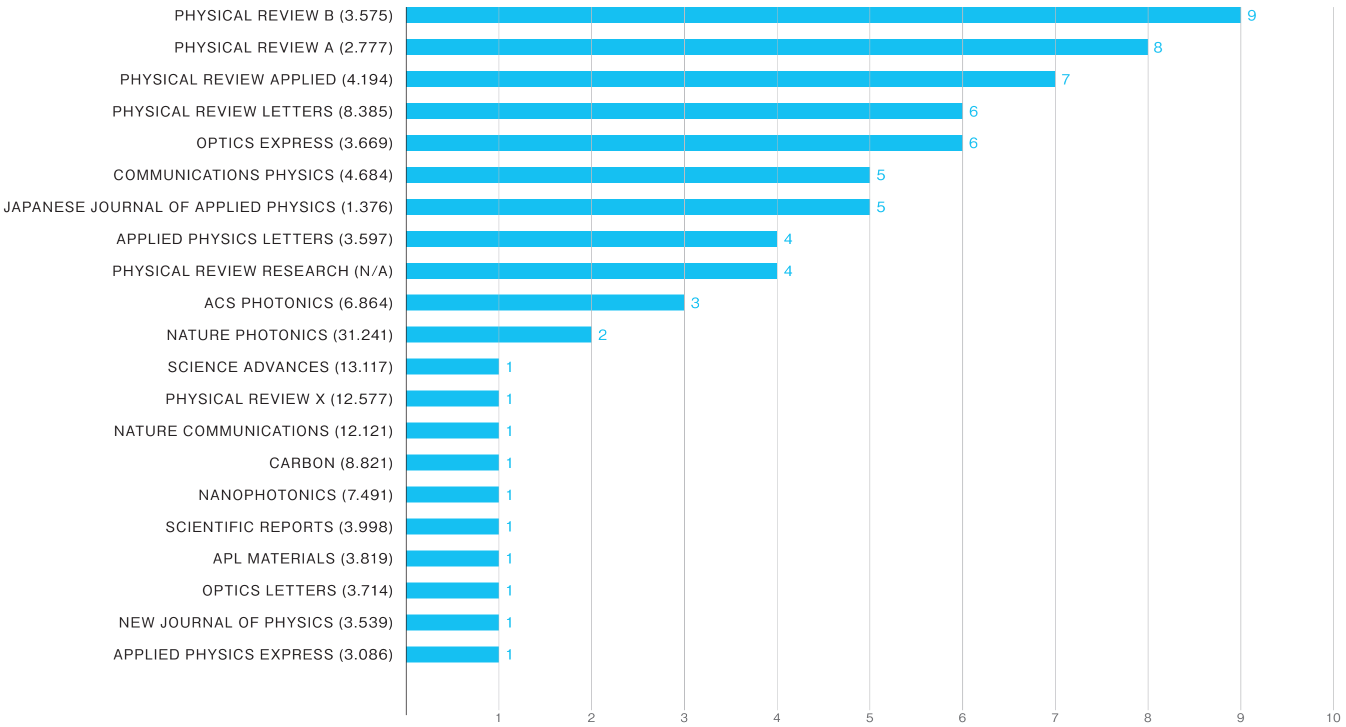
Quantum Communication Experiments in Telecommunication Band Coherent Ising Machine

Distinguished Researcher

Norio Kumada, Shiro Saito, Haruki Sanada, Kengo Nozaki, Takahiro Inagaki, Gento Yamahata, Katsuhiko Nishiguchi, Imran Mahboob, Koji Azuma, Hiroki Mashiko, Hajime Okamoto

Publication List

The total number of NTT Basic Research Laboratories papers published in international journals in 2020 is 84 with an average impact factor of 4.923. The 2019 impact factor of those individual journals are shown in ( ).



Number of Presentations

88
(33 Invited talks)

Number of Patents

79

List of Award Winners

JSAP fellow
Study of Ultimate Control of Electrons Using Silicon Nanodevices **Akira Fujiwara**

The Young Scientists' Prize, the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology
Research on control of spin states and quantum transport in semicondtor quantum nanostructures **Keiko Takase**

2020 PROSE AWARDS in the subject of Chemistry and Physics
Chemical, Gas, and Biosensors for Internet of Things and Related Applications (Elsevier) **Kohji Mitsubayashi, Osamu Niwa, Yuko Ueno**

CHEMINAS Young Excellence Award
Development of mobile plate for cell manipulation using microfabrication technology **Tetsuhiko Teshima**

42th CHEMINAS Poster Award
Three-dimensional extracellular recording by self-folding graphene electrode array
Koji Sakai, Tetsuhiko Teshima, Yuko Ueno, Hiroshi Nakashima, Masumi Yamaguchi

The 2nd Hyogo-Kansai Caterpillar STEM Award, Outstanding Achievement Award
Electrical control of spin-orbit interaction using semiconductor nanowire **Keiko Takase**

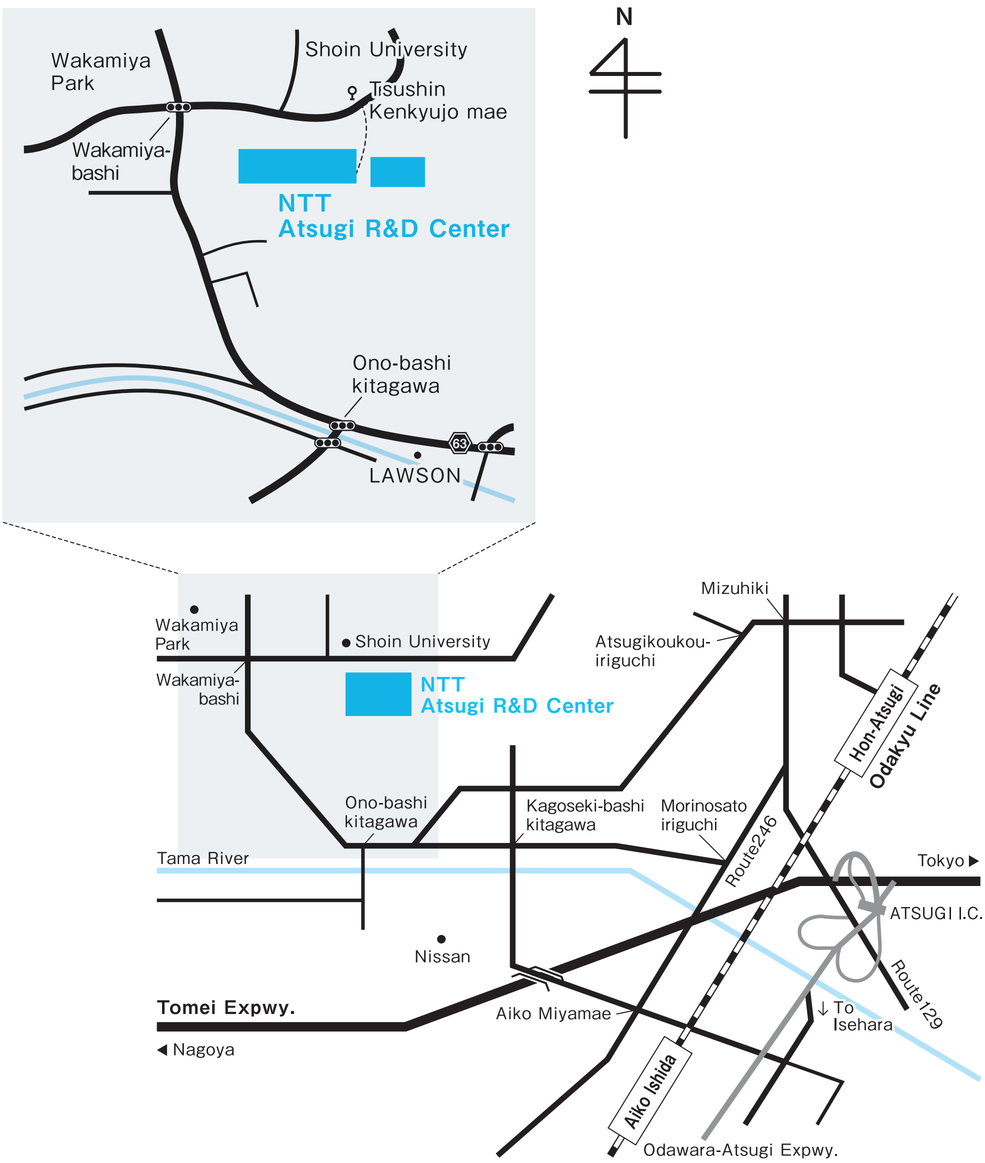
JSAP Paper Award
Electron aspirator using electron–electron scattering in nanoscale silicon
Himma Firdaus, Tokinobu Watanabe, Masahiro Hori, Daniel Moraru, Yasuo Takahashi, Akira Fujiwara, Yukinori Ono

NTT Basic Research Laboratories

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

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

https://www.rd.ntt/e/brl/



Access

By train and bus

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

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

By taxi

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

By car

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