QUANTUM INNOVATION 2024

The International Symposium on Quantum Science, Technology and Innovation


# Proceedings

Date 21-23 October 2024

Tuesday 15 October, 2024

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## Abstrats

QUANTUM INNOVATION 2024

The International Symposium on Quantum Science, Technology and Innovation

## Welcome to Quantum Innovation 2024

It is our pleasure to invite all of you including scientists, engineers, business delegates, young researchers and students to Quantum Innovation 2024, the International Symposium on Quantum Science, Technology and Innovation to be held on 21-23 October 2024.

Quantum Innovation 2024 is the fourth international symposium hosted by Japanese government and research institutes, that aims to bring together multi-disciplined researchers to present and exchange breaking-through ideas in quantum science and technology.

The topics of Quantum Innovation 2024 cover the latest achievements, trends and needs in quantum science and technology including quantum computing, quantum sensing, quantum cryptography and quantum communication.

We look forward to seeing you in Quantum Innovation 2024 and hope you enjoy excellent presentations from distinguished guests, share exciting discoveries and promote fruitful collaborations.

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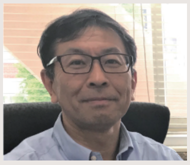

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National Institutes for Quantum Science and Technology（QST）

# Symposium Outline

## Aims

Addressing the state-of-the-art quantum technology

Exploring cooperation on research, application, education and social awareness on quantum technology

We will bring together researchers working on quantum technology and offer a platform for discussions among them. Inviting prominent speakers from abroad and Japan, Quantum Innovation 2024 covers latest development of quantum computing, quantum sensing, quantum cryptography and quantum communication.
We also aim to give young researchers, future quantum working force candidates and aware citizens an overview of fast evolving quantum technology by listening to inspiring talks.

## Scope of the Symposium

### Highlights of the development of quantum technology

- Quantum Computing
- Quantum Sensing
- Quantum Cryptography & Communication

### Development of Infrastructure for the progress of quantum technology

- Promotion of practical applications of quantum technology
- Development of human resources for quantum technology
- Promotion of international collaborations

## Date

21-23 October 2024

## Venue

**sola city Conference Center**

4-6 Kandasurugadai, Chiyoda-ku, Tokyo, 101-0062

## Schedule

| | |
|---|---|
| 21 October | Plenary Sessions |
| 22-23 October | Quantum Computing Track<br>Quantum Sensing Track<br>Quantum Cryptography & Communication Track<br>Poster Session (22 October PM)<br>Special Session on Materials for Future Quantum Information Technologies (23 October AM) |

## Program

Click "Program at a Glance" button in the website menu.

## Speakers

All the speakers are to be invited.

## Participants

The expected participants include researchers, engineers, business delegates, policy makers, administrators, students, and the media people, who share interests in quantum technology and innovation.

## Registration and Admission

All the participants are required to register in advance. Click "Registration" button in the website menu. The registration will be closed as soon as the number of applicants reaches the capacity.

Admission free. There is a membership fee for the party to be held on 21 October.

## Symposium Satellite Workshops

Quantum software, middleware, and controller for near-term quantum computing systems to be held on 17 and 18 October 2024 at Nambu Youichiro Hall, Toyonaka Campus, Osaka University sponsored by JST COI-NEXT Quantum Software Research Hub and MEXT Q-LEAP QuAI Flagship project

Dialogue between Quantum Life Science and Quantum Chemistry: A New Intersection of Knowledge for the Future to be held on 24 October 2024 at Ochanomizu Sola City hosted by QST and Nogoya University

## Symposium Sponsors

Cabinet Office

Ministry of Internal Affairs and Communications (MIC)

Ministry of Education, Culture, Sports, Science and Technology (MEXT)

Ministry of Economy, Trade and Industry (METI)

RIKEN

Japan Science and Technology Agency (JST)

National Institute for Materials Science

National Institutes for Quantum Science and Technology (QST)

National Institute of Advanced Industrial Science and Technology (AIST)

National Institute of Information and Communications Technology (NICT)

Okinawa Institute of Science and Technology Graduate University (OIST)

Osaka University

The University of Tokyo

Tohoku University

Tokai National High Education and Research System

Institute of Science Tokyo

Quantum STrategic industry Alliance for Revolution (Q-STAR)

## About QIH

Quantum technology is bringing a great impact on a wide range of industry. In order to accelerate the progress and make best use of quantum technology, industry, academia and government are expected to collaborate on promoting basic research, technology demonstration, industrialization, intellectual property management and human resource development. For promoting these activities, Japan established Quantum Technology Innovation Hubs in February 2021.

QIH
Quantum Innovation Hubs

- Quantum computation pioneering hub (RIKEN)
- Quantum sensing hub (Science Tokyo (Tokyo Tech))
- Foundational quantum technology and quantum life R&D hub (QST)
- Quantum material hub (NIMS)
- Quantum solution hub (Tohoku University)
- hub of Quantum-based chemistry for industry development (THERS)
- Quantum technology international collaboration hub (OIST)
- Quantum security hub (NICT)
- Quantum computer applications hub (UTokyo & Business alliance)
- Quantum software hub (Osaka University)
- hub of Global research and development for business by quantum-AI technology (AIST)

RIKEN serves as Headquarters of the Hubs to incorporate efforts to advance quantum technology research in Japan.

# Program at a Glance

| Tracks | Contents / Topics |
|---|---|
| **PL** Plenary Sessions | Opening, Government Policy on Quantum Science and Technology, Keynote, Global Quantum Ecosystem, Quantum×AI, Standardization ~ De facto and De jure for Industrialization ~ |
| **CP** Quantum Computing Track | QC with Ions, Atoms and Photons, Semiconductor QC, Superconducting QC, Industrialization of QC, Quantum Annealing, Near-term Quantum Computing, Toward FTQC, Quantum Algorithms and Foundation |
| **SE** Quantum Sensing Track | Solid-State Q. Sensors (1) 2D, SiC / Japan-Germany Diamond NV Collaboration Session Part 1*, Solid-State Q. Sensors (2) Japan-Germany Diamond NV Collaboration Session Part2*, Quantum Optical Sensing*, Quantum Life Science -Impact of nano-scale molecular structures in Living and Eco-Systems for Electron's Quantum behaviours-*,Quantum Life Science -Medical Applications of Quantum Techniques-*, Atom Ion Sensing, Quantum MRI<br>* Q-LEAP 7th IFQMS Joint Session |
| **CC** Quantum Cryptography & Communication Track | Quantum Key Distribution and Its Network, Satellite Quantum Communication, Quantum Communication for Computation, Quantum Network, Social Implementation of Quantum Communication, Quantum Cryptography: Present and Prospects |
| **MA** Special Session | Materials for Future Quantum Information Technologies |

All the times in the program are **Japan Standard Time**(GMT+9) Program at a Glance

## 21 Oct (Mon.)

| | | |
|---|---|---|
| 10:00-10:20 | Opening | PL-01 |
| 10:20-11:40 | Government Policy on Quantum Science and Technology | PL-02 |
| 13:10-14:30 | Keynote | PL-03 |
| 14:30-15:45 | Global Quantum Ecosystem | PL-04 |
| 16:10-16:50 | Quantum × AI | PL-05 |
| 16:50-17:30 | Standardization ~ De facto and De jure for Industrialization ~ | PL-06 |
| 18:30-20:30 | Reception | |

* Q-LEAP 7th IFQMS Joint Session

## 22 Oct (Tue.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 9:00-10:30 | QC with Ions, Atoms and Photons | CP-01 | 9:00-10:30 | Solid-State Q. Sensors (1) 2D, SiC / Japan-Germany Diamond NV Collaboration Session Part 1 | SE-01* | 9:00-10:30 | Quantum Key Distribution and Its Network | CC-01 |
| 10:50-12:20 | Semiconductor QC | CP-02 | 10:50-12:20 | Solid-State Q. Sensors (2) Japan-Germany Diamond NV Collaboration Session Part2 | SE-02* | 10:50-12:20 | Satellite Quantum Communication | CC-02 |
| 13:50-14:50 | Superconducting QC | CP-03 | 13:50-15:20 | Quantum Optical Sensing | SE-03* | 13:50-15:20 | Quantum Communication for Computation | CC-03 |
| 14:50-15:20 | Industrialization of QC | CP-04 | | | | | | |
| 15:40-17:30 | Poster Session | PO | | | | | | |

* Q-LEAP 7th IFQMS Joint Session

**23 Oct (Wed.)**

| Time | Track 1 | Track 2 | Track 3 |
|---|---|---|---|
| 9:00-10:30 | 9:00-10:30 Quantum Annealing CP-05 | 09:00-10:30 Quantum Life Science -Impact of nano-scale molecular structures in Living and Eco-Systems for Electron's Quantum behaviours- SE-04* | 09:00-10:30 Materials for Future Quantum Information Technologies MA-04 |
| 10:50-12:20 | 10:50-12:20 Near-term Quantum Computing CP-06 | 10:50-12:20 Quantum Life Science -Medical Applications of Quantum Techniques- SE-05* | 10:50-12:20 Quantum Network CC-05 |
| 13:50-15:20 | 13:50-15:20 Toward FTQC CP-07 | 13:50-15:20 Atom Ion Sensing SE-06 | 13:50-15:20 Social Implementation of Quantum Communication CC-06 |
| 15:40-17:10 | 15:40-17:10 Quantum Algorithms and Foundation CP-08 | 15:40-17:10 Quantum MRI SE-07 | 15:40-17:10 Quantum Cryptography: Present and Prospects CC-07 |

## Plenary Sessions

All the times in the program are **Japan Standard Time**(GMT+9)

| 21 Oct (Mon.) | Session / Presentation | Chairperson# / Presenter | Affiliation | Abstract PDF |
|---|---|---|---|---|
| 10:00-10:20 | PL-01. Opening | Minoru Yoshida# | RIKEN | |
| 10:00 | Welcome | Yoshinobu Baba | General Chair, Quantum Innovation 2024 Organizing Committee | |
| 10:10 | Welcome | Koichi Hamano | Vice-Minister, Secretary General, Science, Technology and Innovation Policy, Cabinet Office, Government of Japan | |
| 10:15 | Congratulatory speech | (TBA) | | |
| 10:20-11:40 | PL-02. Government Policy on Quantum Science and Technology | Minoru Yoshida# | RIKEN | |
| 10:20 | Japan's Promotion Measures for the Development of Quantum Industries | Daisuke Kawakami | Deputy Secretary General for Secretariat of Science, Technology and Innovation Policy, Cabinet Office | PL-02-01 |
| 10:28 | Australia's National Quantum Strategy | Nicola Powell | Manager, Investment, Engagement and International Section, Quantum Branch, Science Division, Department of Industry, Science and Resources, Australia | PL-02-02 |
| 10:37 | Canada's Quantum Ecosystem and the National Quantum Strategy (NQS) | Michael Rosenblatt | Director of the Federal Science and Technology Policy Directorate and National Quantum Strategy (NQS) Secretariat in Innovation, Science and Economic Development Canada (ISED) | PL-02-03 |
| 10:46 | Denmark's Quantum Strategy | Louise Henneberg | Senior Advisor / Team Leader, International Quantum Hub, Department for Techplomacy, Ministry of Foreign Affairs of Denmark | PL-02-04 |
| 10:55 | EU Quantum Strategy | Oscar Diez | Head of Sector Quantum Computing, European Commission | PL-02-05 |
| 11:04 | German National Quantum Technology Program | Oliver Pieper | German Embassy Tokyo | PL-02-06 |
| 11:13 | Quantum Delta NL: Building the Netherlands Quantum Ecosystem | Jesse Robbers | Director Industry & Digital Infrastructure Quantum Delta NL | PL-02-07 |
| 11:22 | UK's Quantum Strategy | Tom Newby | Deputy Director / Head of Office for Quantum, Department for Science, Innovation and Technology, UK Government | PL-02-08 |
| 11:31 | Updates on U.S. National Quantum Strategy | John Speaks | Regional Technology Officer<br>Economic and Scientific Affairs<br>U.S. Embassy Tokyo | PL-02-09 |
| 11:40-13:10 | Lunch | | | |
| 13:10-14:30 | PL-03. Keynote | Yasunobu Nakamura# | RIKEN | |
| 13:10 | QuEra's path to fault-tolerant quantum computers | Sergio Cantu | QuEra | PL-03-02 |
| 13:50 | Quantum physics in the macroscopic domain | Vlatko Vedral | Oxford U | PL-03-01 |
| 14:30-15:45 | PL-04. Global Quantum Ecosystem | Shunsuke Okada# | Q-STAR | |
| 14:30 | Q-STAR's initiatives for building a quantum ecosystem | Taro Shimada | Q-STAR | PL-04-01 |
| 14:45 | Latest update from QIC | Lisa Lambert | QIC | PL-04-02 |
| 15:00 | Latest update from QuIC | Thierry Botter | QuIC | PL-04-03 |
| 15:15 | QED-C Overview: Looking back and looking ahead | Celia Merzbacher | QED-C | PL-04-04 |
| 15:30 | Developing the global quantum ecosystem | Jonathan Legh-Smith | UKQuantum | PL-04-05 |
| 15:45-16:10 | Break | | | |
| 16:10-16:50 | PL-05. Quantum × AI | Keisuke Fujii# | Osaka U | |
| | | Stefano Carrazza | TII / U Milan | |
| | | Naoki Yamamoto | Keio U | |
| | | François Le Gall | Nagoya U | |
| | | Enrico Rinaldi | Quantinuum | |
| 16:50-17:30 | PL-06. Standardization ~ De facto and De jure for Industrialization ~ | Masahide Sasaki# | NICT | |
| | | Emile Hoskinson | D-Wave | |
| | | Sergio Cantu | QuEra | |
| | | Hao Qin | NUS | |
| | | Masahiro Horibe | AIST | |
| 18:30-20:30 | Reception | | | |

## Quantum Computing Track

All the times in the program are **Japan Standard Time**(GMT+9)

| 22 Oct (Tue.) | Session / Presentation | Chairperson# / Presenter | Affiliation | Abstract PDF |
|---|---|---|---|---|
| 09:00-10:30 | CP-01. QC with Ions, Atoms and Photons | Atsushi Noguchi# | UTokyo / RIKEN | |
| 09:00 | Developing modular microwave trapped ion quantum computers for operation with millions of qubits | Winfried Hensinger | Sussex U | CP-01-01 |
| 09:30 | Scaling quantum computing with a light-matter hybrid architecture | Niccolo Somaschi | Quandela | CP-01-02 |
| 10:00 | A cold-atom quantum computer | Sylvain de Léséleuc | IMS / RIKEN | CP-01-03 |
| 10:30-10:50 | Break | | | |
| 10:50-12:20 | CP-02. Semiconductor QC | Takahiro Mori#<br>Yusuke Kozuka# | AIST<br>NIMS | |
| 10:50 | Scaling up quantum computing with silicon quantum dots | Mark Johnson | Quantum Motion | CP-02-01 |
| 11:20 | Error dynamics during coherent electron spin shuttling | Natalie Foster | SNL | CP-02-02 |
| 11:50 | Toward large-scale integration of silicon spin qubits with low variability | Kimihiko Kato | AIST | CP-02-03 |
| 12:20-13:50 | Lunch | | | |
| 13:50-14:50 | CP-03. Superconducting QC | Yutaka Tabuchi# | RIKEN | |
| 13:50 | Engineering strategies to enable flexible superconducting qubits fabrication | Floris Brulleman | Quantware | CP-03-01 |
| 14:20 | Foundry service for superconducting digital and quantum circuits in G-QuAT/AIST | Mutsuo Hidaka | AIST | CP-03-02 |
| 14:50-15:20 | CP-04. Industrialization of QC | Yutaka Tabuchi# | RIKEN | |
| 14:50 | Toward industrialization of quantum computing technology | Masayuki Shirane | NEC | CP-04-01 |

| 23 Oct (Wed.) | Session / Presentation | Chairperson# / Presenter | Affiliation | Abstract PDF |
|---|---|---|---|---|
| 09:00-10:30 | CP-05. Quantum Annealing | Masaru Hitomi# | Tohoku U | |
| 9:00 | Technical update: Annealing quantum computing's rapid progress | Emile Hoskinson | D-Wave | CP-05-01 |
| 9:30 | Localization detection based on quantum dynamics | Kazue Kudo | Ochanomizu U | CP-05-02 |
| 10:00 | Beyond quantum inspired annealing for quadratic unconstrained binary optimization | Matthieu Parizy | Q-STAR | CP-05-03 |
| 10:30-10:50 | Break | | | |
| 10:50-12:20 | CP-06. Near-term Quantum Computing | Keisuke Fujii# | Osaka U | |
| 10:50 | Design of quantum-HPC hybrid platforms leveraging supercomputers | Miwako Tsuji | RIKEN | CP-06-01 |
| 11:20 | Development of superconducting quantum computer at QIQB, Osaka University | Kazuhisa Ogawa | Osaka U | CP-06-02 |
| 11:50 | Toward open-source software for quantum computing | Stefano Carrazza | U Milan / TII | CP-06-03 |
| 12:20-13:50 | Lunch | | | |
| 13:50-15:20 | CP-07. Toward FTQC | Shigeru Yamashita# | Ritsumeikan U | |
| 13:50 | Constant overhead fault-tolerant quantum computation in realistic physical systems | Pablo Bonilla | Harvard U | CP-07-01 |
| 14:20 | Early fault-tolerant quantum computation in practice | Nobuyuki Yoshioka | UTokyo | CP-07-02 |
| 14:50 | Quantum error correction below the surface code threshold | Michael Newman | Google Quantum AI | CP-07-03 |
| 15:20-15:40 | Break | | | |
| 15:40-17:10 | CP-08. Quantum Algorithms and Foundation | François Le Gall# | Nagoya U | |
| 15:40 | Classical topology & quantum complexity | Tamara Kohler | Stanford U | CP-08-01 |
| 16:10 | Clustering of conditional mutual information and quantum Markov structure at arbitrary temperatures | Tomotaka Kuwahara | RIKEN | CP-08-02 |
| 16:40 | Quantum communication beyond QKD: Position-based cryptography | Harry Buhrman | Quantinuum | CP-08-03 |

## Quantum Sensing Track

All the times in the program are **Japan Standard Time**(GMT+9)

*** Q-LEAP 7th IFQMS Joint Session**

| 22 Oct (Tue.) | Session / Presentation | Chairperson# / Presenter | Affiliation | Abstract PDF |
|---|---|---|---|---|
| 09:00-10:30 | SE-01*. Solid-State Q. Sensors (1) 2D, SiC / Japan-Germany Diamond NV Collaboration Session [JG] Part 1 | Yuichi Yamazaki# | QST | |
| 09:00 | Spin defects in hBN for quantum sensing applications | Jean-Philippe Tetienne | RMIT U | SE-01-01 |
| 09:30 | Room-temperature photoelectrical detection of spins in silicon carbide | Naoya Morioka | Kyoto U | SE-01-02 |
| 10:00 | Creation of spin defects in wide bandgap semiconductors for quantum sensing [JG] | Takeshi Ohshima | QST | SE-01-03 |
| 10:30-10:50 | Break | | | |
| 10:50-12:20 | SE-02*. Solid-State Q. Sensors (2) Japan-Germany Diamond NV Collaboration Session [JG] Part2 | Norikazu Mizuochi# | Kyoto U | |
| 10:50 | Quantum sensing at nanoscale enabled by diamond spin qubits [JG] | Fedor Jelezko | Ulm U | SE-02-01 |
| 11:20 | Quantum sensor-enabled optical magnetic resonance microscopy [JG] | Dominik Bucher | TUM | SE-02-02 |
| 11:50 | Potential of diamond quantum sensors based on spin-qubits of NV centers [JG] | Mutsuko Hatano | Science Tokyo (Tokyo Tech) | SE-02-03 |
| 12:20-13:50 | Lunch | | | |
| 13:50-15:20 | SE-03*. Quantum Optical Sensing | Ryosuke Shimizu# | UEC | |
| 13:50 | Time-resolved photon antibunching in single molecules | Gordon Hedley | U Glasgow | SE-03-01 |
| 14:20 | Theory of time-resolved optical spectroscopy with quantum entangled photons | Yuta Fujihashi | UEC | SE-03-02 |
| 14:50 | Quantum-enhanced measurements of molecular concentration and chirality using entangled photon pairs | Korenobu Matsuzaki | RIKEN | SE-03-03 |

*** Q-LEAP 7th IFQMS Joint Session**

| 23 Oct (Wed.) | Session / Presentation | Chairperson# / Presenter | Affiliation | Abstract PDF |
|---|---|---|---|---|
| 09:00-10:30 | SE-04*. Impact of nano-scale molecular structures in Living and Eco-Systems for Electron's Quantum behaviours | Noriko Hiroi# | KAIT / Keio U | |
| 09:00 | Chiral induced spin selectivity effect in various biomolecular systems | Suryakant Mishra | LANL | SE-04-01 |
| 09:30 | Structural basis for color tuning and ion selectivity in potassium-selective channelrhodopsins | Hideaki Kato | UTokyo | SE-04-02 |
| 10:00 | Nano-fluids at deep-sea hydrothermal vents | Ryuhei Nakamura | RIKEN | SE-04-03 |
| 10:30-10:50 | Break | | | |
| 10:50-12:20 | SE-05*. Quantum Life Science -Medical Applications of Quantum Techniques- | Natsuko Miura# | KAIT / OMU | |
| 10:50 | Leveraging hyperpolarized spin states to visualize biochemical processes | Kayvan Keshari | Memorial Sloan Kettering Cancer Center | SE-05-01 |
| 11:20 | Development of oligopeptide DNP MRI molecular probes for in vivo studies | Yohei Kondo | Science Tokyo (Tokyo Tech) | SE-05-02 |
| 11:50 | Next-generation cancer therapy pioneered by the fusion of quantum bioscience and robotic surgery | Nobu Ohshima | Kyoto U | SE-05-03 |
| 12:20-13:50 | Lunch | | | |
| 13:50-15:20 | SE-06. Atom Ion Sensing | Tomoya Sato# | Science Tokyo (Tokyo Tech) | |
| 13:50 | Advances in quantum sensing for gravity cartography (TBC) | Michael Holynski | U Birmingham | SE-06-01 |
| 14:20 | Quantum sensing with atoms and ions | Paul Hamilton | UCLA | SE-06-02 |
| 14:50 | Advances in optical frequency comb technology and its impact on atomic and molecular sensing | Hajime Inaba | AIST | SE-06-03 |
| 15:20-15:40 | Break | | | |
| 15:40-17:10 | SE-07. Quantum MRI | Masayuki Matsuo# | Gifu U | |
| 15:40 | Imaging metabolism and physiology in cancer | Murali Cherukuri | NIH | SE-07-01 |
| 16:20 | In vitro evaluation of cell metabolism by hyperpolarized 13C-NMR and future biological applications | Natsuko Miura | OMU | SE-07-02 |
| 16:40 | Development of DNP-MRI visualizing alterations of kidney cancer-associated genes | Hisashi Hasumi | YCU | SE-07-03 |

## Quantum Cryptography & Communication Track

All the times in the program are **Japan Standard Time**(GMT+9)

| 22 Oct (Tue.) | Session / Presentation | Chairperson# / Presenter | Affiliation | Abstract PDF |
|---|---|---|---|---|
| 09:00-10:30 | CC-01. Quantum Key Distribution and Its Network | Akihisa Tomita# | Hokkaido U | |
| 09:00 | Transitioning to quantum secure networks | Shinya Murai | Toshiba Digital Solutions | CC-01-01 |
| 09:30 | Integrating quantum key distribution with optical communication networks | Takuya Hirano | Gakushuin U | CC-01-02 |
| 10:00 | A quantum-safe network testbed for versatile use cases and applications: National Quantum-Safe Network, Singapore | Hao Qin | NUS | CC-01-03 |
| 10:30-10:50 | Break | | | |
| 10:50-12:20 | CC-02. Satellite Quantum Communication | Masahiro Takeoka# | Keio U | |
| 10:50 | Constellations for space quantum communications | Daniel Oi | U Strathclyde | CC-02-01 |
| 11:20 | Satellite-based QKD R&D and commercialization trends | Saori Yokote | SKY Perfect JSAT | CC-02-02 |
| 11:50 | Secure key generation via optical communication between ISS and a vehicle. —Toward satellite QKD — | Shunsuke Ozawa | NICT | CC-02-03 |
| 12:20-13:50 | Lunch | | | |
| 13:50-15:20 | CC-03. Quantum Communication for Computation | William Munro# | OIST | |
| 13:50 | Recent progress towards enabling the scalability of quantum hardware using quantum communications | Hanhee Paik | IBM | CC-03-01 |
| 14:20 | Entanglement-efficient bipartite-distributed quantum computing | Mio Murao | UTokyo | CC-03-02 |
| 14:50 | Development of a spin ensemble-based quantum transducer | Yuimaru Kubo | OIST | CC-03-03 |

| 23 Oct (Wed.) | Session / Presentation | Chairperson# / Presenter | Affiliation | Abstract PDF |
|---|---|---|---|---|
| 09:00-10:30 | MA-04. Materials for Future Quantum Information Technologies | Yusuke Kozuka# | NIMS | |
| 09:00 | Quantum point defects in wide band gap semiconductors: Donor properties in ZnO and charge states of diamond | Kai-Mei Fu | U Washington | MA-04-01 |
| 09:30 | Exploring quantum devices with new materials | Tomohiro Otsuka | Tohoku U | MA-04-02 |
| 10:00 | Quantum computation using electron wave packets | Michihisa Yamamoto | UTokyo | MA-04-03 |
| 10:30-10:50 | Break | | | |
| 10:50-12:20 | CC-05. Quantum Network | Koji Azuma# | NTT | |
| 10:50 | Single-photon emitter using a rare-earth atom confined in optical fiber | Kaoru Sanaka | TUS | CC-05-01 |
| 11:20 | Development of frequency-multiplexed quantum repeater system | Tomoyuki Horikiri | YNU | CC-05-02 |
| 11:50 | Graph state generation for quantum networks | Sophia Economou | Virginia Tech | CC-05-03 |
| 12:20-13:50 | Lunch | | | |
| 13:50-15:20 | CC-06. Social Implementation of Quantum Communication | Osamu Toba# | Q-STAR | |
| 13:50 | Post-quantum cryptography (PQC) today, tomorrow, and challenges | Atsushi Yamada | ISARA | CC-06-01 |
| 14:20 | The next-generation quantum technology ecosystem | Jesse Robbers | Quantum Delta NA | CC-06-02 |
| 14:50 | A case: cybersecurity of financial Institutions in quantum computer Era | Yuto Takahashi | JRI | CC-06-03 |
| 15:20-15:40 | Break | | | |
| 15:40-17:10 | CC-07. Quantum Cryptography: Present and Prospects | Masato Koashi# | UTokyo | |
| 15:40 | (TBA) | Thomas van Himbeeck | Télécom Paris | CC-07-01 |
| 16:10 | Computationally hard problems for post-quantum cryptography | Yusuke Aikawa | UTokyo | CC-07-02 |
| 16:40 | Recent progress on QAM/QNSC optical transmission | Masataka Nakazawa | Tohoku U | CC-07-03 |

# Poster Session
# PO-CP : Posters on Quantum Computing

All the times in the program are **Japan Standard Time**(GMT+9)

| 22 Oct (Tue.) | Session / Presentation | Name | Affiliation | Poster ID |
|---|---|---|---|---|
| 15:40-17:30 | High-rate generation of optical squeezed single-photon states by generalized photon subtraction | Hiroko Tomoda | UTokyo | PO-CP-01 |
| | Theoretical approach of dissipation of reservoir computing using spin qubits | Shion Mifune | Teikyo U | PO-CP-02 |
| | Demonstration of continuous-variable quantum kernel method with optical squeezed-state encoding | Keitaro Anai | UTokyo | PO-CP-03 |
| | Controlled extra longitudinal magnetic fields improve the performance of quantum annealing for maximum weighted independent set | Tomohiro Hattori | Keio U | PO-CP-04 |
| | Analysis of hybrid method for variable-reduction problem size dependency | Shuta Kikuchi | Keio U | PO-CP-05 |
| | 99.99% Fidelity quantum gates via pulse shaping in five-qubit spin device | Yi-Hsien Wu | RIKEN | PO-CP-06 |
| | Spatio-temporal recognition of charge noise sources in $^{28}$Si/SiGe spin qubits | Juan S. Rojas-Arias | RIKEN | PO-CP-07 |
| | Towards magnon-mediated microwave photon-photon nonlinearities | steven a sagona-stophel | OIST | PO-CP-09 |
| | Rydberg-state detection in a small ensemble of trapped electrons | Mikhail Belianchikov | OIST | PO-CP-10 |
| | Coherent information for CSS codes under decoherence | Ryotaro Niwa | UTokyo | PO-CP-11 |
| | Towards dark valleytronics in a monolayer semiconductor | XING ZHU | OIST | PO-CP-12 |
| | Two photon generation using optical nanofiber-trapped cold atoms | Zohreh Shahrabifarahani | OIST | PO-CP-13 |
| | Scalable, frequency-tunable transmon qubit system in a 3D-integrated pogo-pin package | Zhiguang Yan | RIKEN | PO-CP-14 |
| | Quasioptical approach to microwave field enhancement in electron-on-helium qubit systems | Natalia Morais | OIST | PO-CP-15 |
| | Impact of Interface trap charge on coulomb oscillation in MOS-type quantum dots | Hidehiro Asai | AIST | PO-CP-16 |
| | Development of a dynamic route direction system for real-world large-scale mobile robots using quantum annealing | Thinh NguyenQuang | Tohoku U | PO-CP-17 |
| | Direct sum theorems beyond query complexity | Daiki Suruga | Nagoya U | PO-CP-18 |
| | Toward a control system for quantum computers across diverse physical platforms | Ryutaro Ohira | QuEL | PO-CP-19 |
| | Modular quantum extreme reservoir computing | Hon Wai Lau | OIST | PO-CP-20 |
| | Mitigation of noisy quantum probability densities using machine learning | Leonardo Placidi | Quantinuum / Osaka U | PO-CP-21 |
| | A hierarchical GUI-based web app for quantum circuit transpilation and qubit Allocation | Kishou Sotokawa | Keio U | PO-CP-22 |
| | Utilizing don't-cares to minimize CNOTs in synthesizing NNA compliant quantum circuits | David Clarino | Ritsumeikan U | PO-CP-23 |
| | Observation of anti-bunching of the fluorescence from single atom on atom array | Yuya Maeda | Osaka U | PO-CP-24 |
| | Quantitative analysis of classical and quantum neural networks using a tic-tac-toe engine | Suzukaze Kamei | Keio U | PO-CP-25 |
| | Scalable connection of physical qubits to quantum error correction systems using regular ethernet | Jan-Erik R. Wichmann | RIKEN | PO-CP-26 |
| | Performance of academic and industrial silicon spin-qubits | Ik Kyeong Jin | RIKEN | PO-CP-27 |
| | Developing experimental setup for measurement of electron mobility on the surface of neon | Ka Wing Yip | OIST | PO-CP-28 |
| | Advantage of QML from general computational advantages | Natsuto Isogai | UTokyo | PO-CP-29 |
| | One-to-one correspondence between deterministic port-based teleportation and unitary estimation | Satoshi Yoshida | UTokyo | PO-CP-30 |
| | Selective frequency conversion by optical frequency tweezers | Shunsuke Hiraoka | Osaka U | PO-CP-31 |
| | Uncovering bottlenecks in quantum Internet applications via blind variational quantum computing | Masaki Nagai | Keio U | PO-CP-32 |
| | Enhancing superconducting quantum processor performance through pre-processing techniques | Hana Ebi | Keio U | PO-CP-33 |
| | High gain and bandwidth josephson parametric amplifier influenced by fabry-perot interference | Jesper Ilves | UTokyo | PO-CP-34 |
| | Isotope selection and sympathetic cooling of $^{40}Ca^{+}$ and $^{44}Ca^{+}$ in a through-hole surface-electrode trap | Masanari Miyamoto | Osaka U | PO-CP-35 |
| | Hidden quantum memory: Is memory there when somebody looks? | Philip Taranto | UTokyo | PO-CP-36 |
| | Chebyshev approximated variational coupled cluster for quantum computing | Luca Klaus Erhart | Osaka U | PO-CP-37 |
| | Optimized quantum folding barrett reduction for quantum modular multipliers | Jian Zhang | Hanyang U | PO-CP-38 |
| | Making a guideline for constructing a trapped-Ion quantum node | Monet Tokuyama | Keio U | PO-CP-39 |

| 22 Oct (Tue.) | Session / Presentation | Name | Affiliation | Poster ID |
|---|---|---|---|---|
| 15:40-17:30 | Improving mapping to nearest neighbor architecture by using gaussian elimination-based method by changing qubits' order | ZANHE QI | Ritsumeikan U | PO-CP-40 |
| | Harnessing quantum-Inspired algorithms to Identify optimal adsorption sites and energies on high-entropy alloys | Tuan Minh Do | Osaka U | PO-CP-41 |
| | Scalable circuit depth reduction in feedback-based quantum optimization with a quadratic approximation | Ken Okada | Osaka U | PO-CP-42 |
| | Universal neural network potentials as atomic descriptors: Toward efficient and accurate chemical property prediction using quantum machine learning | Tomoya Shiota | Osaka U | PO-CP-43 |
| | Optical quantum computing with hybrid squeezed cat code | Shohei Kiryu | Hokkaido U | PO-CP-44 |
| | Ab initio extended hubbard model of short polyenes for efficient quantum computing | Yuichiro Yoshida | Osaka U | PO-CP-45 |
| | Quantum algorithm for shortest vector problems with folded spectrum method | Kota Mizuno | SIT | PO-CP-46 |
| | Wave function refinement via quantum power lanczos method using generalized quantum signal processing | Viktor Khinevich | Osaka U | PO-CP-47 |
| | Integrating a miniature cavity into a linear ion trap | Savelii Dudoladov | OIST | PO-CP-48 |

# Poster Session
## PO-SE : Posters on Quantum Sensing*

* Q-LEAP 7th IFQMS Joint Session

All the times in the program are **Japan Standard Time**(GMT+9)

| 22 Oct (Tue.) | Session / Presentation | Name | Affiliation | Poster ID |
|---|---|---|---|---|
| 15:40-17:30 | Fluorescent nanodiamond–based thermometry in rat mammary tissue | Tatsuhiko Imaoka | QST | PO-SE-01 |
| | Unveiling the photoactivation mechanism of photoactivated adenylate cyclase OaPAC by hybrid QM/MM simulation | Masahiko Taguchi | Tohoku U | PO-SE-02 |
| | Ultra-broadband quantum infrared spectroscopy | Toshiyuki Tashima | Kyoto U | PO-SE-03 |
| | Observation of the delocalized amide proton in a hydrogen bond by neutron crystallography | Takeshi Hiromoto | QST | PO-SE-04 |
| | Investigation of the peptide-bond structures in an iron-sulfur protein by high-resolution neutron structure analysis | Yu Hirano | QST | PO-SE-05 |
| | Spectroscopic imaging with diamond submicron particles containing nitrogen-vacancy centers and a single multimode fiber endoscope | Kazuki Ota | Kyoto U | PO-SE-06 |
| | Spectrally resolved density matrix measurement with delay-line-anode single-photon imagers | Ozora Iso | UEC | PO-SE-07 |
| | Relationship between intracellular dynamic enzyme assembly and their reaction efficiency using fluorescence microscopy and hyperpolarized $^{13}C$ NMR | Tomoto Ura | U Tsukuba | PO-SE-08 |
| | Design of flux concentrators for NV-diamond magnetoencephalography | Tingyu Zhu | UTokyo | PO-SE-09 |
| | Machine learning force fields for acetic acid and acetaldehyde in water | HIsashi Ishida | QST | PO-SE-10 |
| | Conditions for observing the effect of a single spin on a mechanical oscillator | Evangelia Aspropotamiti | UCPH | PO-SE-11 |
| | Dephasing factor of $NV^-$ center coherence with homogeneous $T_2^*$ distribution | Chikara Shinei | U Tsukuba | PO-SE-12 |
| | Single photon emission from defect centers in hexagonal boron nitride with selective anti-Stokes excitation | Yudai Okashiro | Kyoto U | PO-SE-14 |
| | Dislocation density dependence of ODMR spectrum simulations for improving magnetic sensitivity | Moriyoshi Haruyama | AIST | PO-SE-15 |
| | Prototyping of active shielding systems for moving target denoising | Xinyu Cao | UTokyo | PO-SE-16 |
| | Magnetoencephalography source estimation based on multipole modeling of magnetic fields and current sources | Motofumi Fushimi | UTokyo | PO-SE-17 |
| | Magnetically-levitated high-Q resonator for ultraprecise sensing | Shilu Tian | OIST | PO-SE-18 |
| | Linear lie algebra parameterisations for quantum fisher information and dynamics | Tatiana Iakovleva | OIST | PO-SE-19 |
| | Development of 20 cm sample bore size dynamic nuclear polarization (DNP)-MRI at 16 mT and redox metabolic imaging of acute hepatitis rat model | Hinako Eto | Kyushu U | PO-SE-20 |
| | Entanglement structure of real subspaces in composite complex Hilbert spaces | Jisho Miyazaki | UTokyo | PO-SE-21 |
| | Quantum sensing based on a hollow core whispering gallery resonator and nitrogen vacancy centers in diamond | Mohammed Zia Jalaludeen | OIST | PO-SE-22 |
| | Development of milligram-scale optomechanical torsion pendulum : Towards quantum noise-level sensitivity | Ryosuke Sugimoto | UTokyo | PO-SE-23 |
| | Laser beam induced charge collection for defect mapping and spin state readout in diamond | Ralf Wunderlich | U Leipzig | PO-SE-24 |
| | Nanotube stamping for intracellular multimodal quantum sensing | Shuntaro Usui | Waseda U | PO-SE-25 |
| | Development of diamond ring cavities for sensitive and high-resolution quantum sensing | Kosuke Takada | TUT | PO-SE-26 |
| | Thermometer based on a superconducting qubit | Dmitrii S. Lvov | Aalto U | PO-SE-27 |
| | Superconducting qubit thermometry of a mesoscopic heat bath | Sergei Lemziakov | Aalto U | PO-SE-28 |
| | Functional analyses of chicken cryptochrome 4 and red opsin for magnetoreception | Naoki Kimata | Waseda U | PO-SE-29 |
| | Local temperature control using near-infrared light combined with temperature measurement using quantum dots can evaluate temperature-dependent changes in cerebral blood flow | Masaki Yoshioka | QST | PO-SE-31 |
| | High frequency AC magnetic field imaging by CW-ODMR measurement of RF-dressed state in scanning diamond probe | Kazuma Okura | Keio U | PO-SE-32 |
| | Effect of ionic strength on the generation of dynamic electron polarization under photo-irradiation of xanthene dye-nitroxide radical aqueous solution | Masatoshi Kato | Kanagawa U | PO-SE-33 |
| | Measuring the full stress tensor components near dislocation in diamond | Takeyuki Tsuji | NIMS | PO-SE-34 |
| | Superconducting nanostrip photon detector for mid infrared wavelength region | Shigehito Miki | NICT | PO-SE-35 |
| | Development of multichannel diamond quantum magnetometer for magnetoencephalography of small animals | Atsumi Yoshimura | Science Tokyo (Tokyo Tech) | PO-SE-36 |
| | Simulating electronic properties and quantum dynamics in natural and artificial photosynthetic systems | Takatoshi Fujita | QST | PO-SE-37 |
| | Ground and excited states of spin qubits calculated using quantum computer | Hirofumi Nishi | Quemix | PO-SE-38 |
| | Comparison of cryptochrome structures among the mammals in the extreme environments | Sora Endo | KAIT | PO-SE-39 |

| 22 Oct (Tue.) | Session / Presentation | Name | Affiliation | Poster ID |
|---|---|---|---|---|
| 15:40-17:30 | Nitrogen vacancy centre pairs aim to boost sensitivity | David Herbschleb | Kyoto U | PO-SE-40 |
| | Study on the photoionization path in PDMR of silicon vacancies in silicon carbide | Kazuki Okajima | Kyoto U | PO-SE-41 |
| | Tin-vacancy (SnV) center in detonation nanodiamond | Masanao Ohori | Kyoto U | PO-SE-42 |
| | Reconstruction of cardiac current source by magnetocardiography with cylindrical sensor array | Wenyu Shang | Utokyo | PO-SE-43 |
| | High sensitive multiplexed imaging of AC magnetic field and temperature using RF-dressed states of electron spins in diamond | Yuma Itabashi | Keio U | PO-SE-44 |
| | Enhancement in the sensitivity of diamond quantum sensor using magnetic flux concentrator for magnetoencephalography of a small animal | Kazuki Shirota | Science Tokyo (Tokyo Tech) | PO-SE-45 |
| | Improving spin dephasing time of perfectly aligned NV center in CVD diamond | Tzyy Zheng Neo | Science Tokyo (Tokyo Tech) | PO-SE-46 |
| | Bandgap engineering of newly developed Ag–Mn–Sn–S quantum dots | Chang Jiang | Nagoya U | PO-SE-47 |
| | Radio frequency discharge apparatus for studying spin transfer from solid surfaces to metastable helium gas | Haruka Maruyama | TUAT / Science Tokyo (Tokyo Tech) | PO-SE-48 |
| | Highly sensitive photocurrent-based AC magnetic sensing by using lock-in detection | Ei Shigematsu | Kyoto U | PO-SE-49 |
| | Electron chain on liquid helium as a quantum sensor | Wanting He | OIST | PO-SE-50 |
| | Exploring quantum and quantum-Inspired acceleration in large-scale, high-dimensional neural data analyses | Kei Majima | QST | PO-SE-51 |
| | Characterization of preferentially oriented NV centers generated by CVD growth on diamond {111} facets in inverted pyramid-shaped holes | Koki Imuta | Keio U | PO-SE-52 |
| | Photoreaction prediction of magnetoreceptor candidate molecule cryptochrome4 in the natural light environments | Hiroaki Otsuka | Waseda U | PO-SE-53 |
| | Magnetic field sensing by NV center ensemble in nanodiamonds | Naoya Kamiyama | Kyoto U | PO-SE-54 |
| | Polarization-entangled photon source for wavelength-division multiplexing | Tomoya Okita | UEC | PO-SE-55 |
| | Large kinetic isotope effect in the scavenging reaction of a nitronyl nitroxide radical by a water-soluble vitamin E analog in aqueous buffer solutions | Ikuo Nakanishi | QST | PO-SE-56 |
| | Rapid sensing of rydberg states in electrons on helium via radio-frequency reflectometry | Juiyin Lin | OIST | PO-SE-57 |
| | Highly-sensitive magnetic-field measurement outside a magnetic shield using diamond quantum magnetometers with gradiometer configuration | Aoi Nakatsuka | Science Tokyo (Tokyo Tech) | PO-SE-58 |
| | Precision AC current ratio measurement using a current comparator with a diamond quantum magnetic sensor | Hidekazu Muramatsu | AIST | PO-SE-59 |
| | Sensing electron dynamics in a copper metalloprotein active site by Cu L edge resonant inelastic x-ray scattering | Ralph Ugalino | QST | PO-SE-60 |
| | Creating controlled NV systems in (001) and (111) diamond for quantum technologies | Lillian B Hughes | UCSB | PO-SE-61 |
| | X-ray absorption near edge structures of blue copper proteins | Kentaro Fujii | QST | PO-SE-62 |
| | Heteroepitaxial (111) diamond quantum sensors with preferentially aligned nitrogen-vacancy centers for an electric vehicle battery monitor | Kenichi Kajiyama | Science Tokyo (Tokyo Tech) | PO-SE-63 |
| | Optimally controlled spin amplification in persistent-current artificial atoms | Ivan Iakoupov | OIST | PO-SE-64 |
| | All-optical coherent state formation of a lead-vacancy center in diamond | Yiyang Chen | Science Tokyo (Tokyo Tech) | PO-SE-65 |
| | Portable quantum magnetic field sensor based on NV center in diamond | Sungdan Lee | LG E | PO-SE-66 |
| | Evaluation of diamond quantum magnetometer for magnetoencephalography of small animals with dry phantom | Yuta Kainuma | Science Tokyo (Tokyo Tech) | PO-SE-67 |
| | CVD synthesis of thick diamond film containing high-density NV centers aligned in [111] direction | Riku Kawase | Kyoto U | PO-SE-68 |
| | Two-photon interference with remote lead-vacancy centers in diamond over 10 K | Peng Wang | Science Tokyo (Tokyo Tech) | PO-SE-69 |
| | Identical photon generation from charge-stabilized lead-vacancy centers in diamond | Ryotaro Abe | Science Tokyo (Tokyo Tech) | PO-SE-70 |
| | Cross polarization rejection towards resonant two-photon interference of diamond quantum emitters | Yuto Shirayama | Science Tokyo (Tokyo Tech) | PO-SE-71 |
| | Extension of spin dephasing time of millimeter-scale ensemble NV centers by suppressing magnetic and strain field inhomogeneities | Ikuya Fujisaki | Science Tokyo (Tokyo Tech) | PO-SE-72 |
| | Observation of an anisotropic dispersion effect in frequency-entangled photons | Takahisa Kuwana | UEC | PO-SE-73 |
| | Creation of $NV^-$ center in type-Ib diamonds by post and in-situ annealing with electron beam irradiation | Shuya Ishii | QST | PO-SE-74 |
| | Noise spectroscopy for estimation of correlation time of the environment noise surrounding NV-NV pair | Kosuke Kimura | Gunma U / QST | PO-SE-75 |
| | Imaging micron-scale distribution of amplitude and phase of AC magnetic field around micro-circuit with diamond quantum sensor | Fuki Otsubo | Keio U | PO-SE-76 |
| | Analysis of electron spin double resonance signals in diamond under non-weak excitation considering effect of $^{14}N$ nuclear spin | Rui Suzuki | Keio U | PO-SE-77 |

# Poster Session
## PO-CC : Posters on Quantum Cryptography & Communication

All the times in the program are **Japan Standard Time**(GMT+9)

| 22 Oct (Tue.) | Session / Presentation | Name | Affiliation | Poster ID |
|---|---|---|---|---|
| 15:40-17:30 | An implementation of a key routing method by centralized and distributed management for large-scale QKD networks | Ririka Takahashi | Toshiba | PO-CC-01 |
| | Photo-CIDNP detection methods for $^{19}$F-containing compounds | Shoya Shiromizu | Gifu U | PO-CC-02 |
| | Multiplexed QKD system and its evaluation | Akira Murakami | Toshiba | PO-CC-03 |
| | Intensity correlations in decoy-state BB84 quantum key distribution systems | Daniil Trefilov | U Vigo | PO-CC-04 |
| | Mutual entity authentication of quantum key distribution network system using authentication qubits | Byungkwon Park | SDT | PO-CC-05 |
| | Adaptive post quantum cryptography assisted quantum key distribution networking for practical end-to-end quantum-secured service | Chankyun Lee | KISTI | PO-CC-06 |
| | Enhancing quantum key distribution with entanglement distillation and classical advantage distillation | Shin Sun | OIST | PO-CC-07 |
| | Disti-mator: an entanglement distillation-based state estimator | Joshua Carlo A Casapao | OIST | PO-CC-08 |
| | Heralding higher-dimensional bell and greenberger-horne-zeilinger states using multiport splitters | Daniel Bhatti | OIST | PO-CC-09 |
| | A self-healing quantum network with all-transparent optical routers | Xiao Duan | NTU | PO-CC-10 |
| | Efficient secret reconstruction quantum circuit for binary stabilizer-based quantum secret sharing | Shogo Chiwaki | Science Tokyo (Tokyo Tech) | PO-CC-11 |
| | Threshold quantum distillation | Shashank Gupta | OIST | PO-CC-12 |
| | General treatment of gaussian trusted noise in continuous-variable quantum key distribution | Shinichiro Yamano | UTokyo | PO-CC-13 |
| | Ultrafast uniformed quantum manipulation in InAs quantum dot ensemble embedded in optical resonator | Yushiro Takahashi | Keio U | PO-CC-14 |
| | Simple quantum state tomography of single-photon-based multipartite entanglement | Joe Yoshimoto | Keio U | PO-CC-15 |
| | Photon echo enhancement from InAs QDs via adiabatic rapid passage and time-resolved measurement using frequency up-conversion | Yuta Kochi | Keio U | PO-CC-16 |
| | Quantum network sensing via the efficient multi-partite entanglement distribution in a lossy star network | Yoshihiro Ueda | Keio U | PO-CC-17 |
| | Port-based telecloning: a generalization of port-based teleportation to the many receivers' case | Reiji Okada | Nagoya U | PO-CC-18 |
| | Device-independent conference key agreement with mild detection efficiency | Makoto Ishihara | Keio U | PO-CC-19 |
| | Wideband balanced detector for quantum applications | Miwa Naka | Gakushuin U | PO-CC-20 |
| | Consequences of preserving reversibility in quantum superchannels | Wataru Yokojima | UTokyo | PO-CC-21 |
| | A quantum-resistant photonic hash function | Rikuto Fushio | Blocq | PO-CC-22 |
| | System configuration for multi-party quantum entanglement protocols | Atsushi Taniguchi | NTT NIL | PO-CC-23 |
| | Optical evaluation of diamond photonic crystals with embedded ensemble NV centers | kiyotaka Sato | YNU | PO-CC-24 |
| | Ruleset generation and execution in quantum internet applications | Rei Kawano | Keio U | PO-CC-25 |
| | Demonstration of quantum frequency conversion in the singly resonant cavity | Shoichi Murakami | Osaka U | PO-CC-26 |
| | Performance of quantum networks using heterogeneous link architectures | Kento Samuel Soon | Keio U | PO-CC-27 |
| | A scalable framework for automation of quantum network experiments | Amin Taherkhani | Keio U | PO-CC-28 |
| | Generation of 2D-graph states of itinerant microwave photonic qubits based on time-frequency dimension with a fixed-frequency circuit | Zhiling Wang | RIKEN | PO-CC-29 |
| | Bright illumination attack on BB84 with passive and asymmetric basis selection | Toshitsugu Kato | Hokkaido U | PO-CC-30 |
| | An efficient erasure decoder and quantum multiplexing using hypergraph product codes | Nicholas S Connolly | OIST | PO-CC-31 |
| | Phase stabilization using two different wavelengths for single-photon entanglement swapping | Eiichiro Kawai | Keio U | PO-CC-32 |
| | Towards cavity quantum electrodynamics with barium ions | Diptaranjan Das | OIST | PO-CC-33 |
| | Quantum fingerprinting without ancilla qubits | Ryoma Senda | Mie U | PO-CC-34 |
| | Equivalence between operator spreading and Information propagation | Cheng Shang | UTokyo | PO-CC-35 |

# Abstracts

| Tracks | Contents / Topics |
|---|---|
| **PL** Plenary Sessions | Opening, Government Policy on Quantum Science and Technology, Keynote, Global Quantum Ecosystem, Quantum×AI, Standardization ~ De facto and De jure for Industrialization ~ |
| **CP** Quantum Computing Track | QC with Ions, Atoms and Photons, Semiconductor QC, Superconducting QC, Industrialization of QC, Quantum Annealing, Near-term Quantum Computing, Toward FTQC, Quantum Algorithms and Foundation |
| **SE** Quantum Sensing Track | Solid-State Q. Sensors (1) 2D, SiC / Japan-Germany Diamond NV Collaboration Session Part 1*, Solid-State Q. Sensors (2) Japan-Germany Diamond NV Collaboration Session Part2*, Quantum Optical Sensing*, Quantum Life Science -Impact of nano-scale molecular structures in Living and Eco-Systems for Electron's Quantum behaviours-*,Quantum Life Science -Medical Applications of Quantum Techniques-*, Atom Ion Sensing, Quantum MRI<br>* Q-LEAP 7th IFQMS Joint Session |
| **CC** Quantum Cryptography & Communication Track | Quantum Key Distribution and Its Network, Satellite Quantum Communication, Quantum Communication for Computation, Quantum Network, Social Implementation of Quantum Communication, Quantum Cryptography: Present and Prospects |
| **MA** Special Session | Materials for Future Quantum Information Technologies |

PL-02-01

# Japan's Promotion Measures for the Development of Quantum Industries

**Daisuke Kawakami**

*Secretariat of Science, Technology and Innovation Policy*

## Biography

Dr. Daisuke KAWAKAMI graduated from Kyoto University and completed master's program in chemistry, Graduate School of Science, Kyoto University in 1993. He joined Toray Industries, Inc., and was assigned to Fibers & Textiles Research Laboratory in 1993. He received Ph.D. in engineering from Graduate School of Organic Engineering, Faculty of Engineering, Tokyo Institute of Technology in 2008. He has been the vice president of Toray Industries (America), Inc. since 2016. After serving as Director for Life Innovation Business Strategy Planning Department from 2016 to 2023, he was appointed as Deputy Director General for Science, Technology and Innovation Policy, Cabinet Office, in 2023.

## Abstract

Japan has so far formulated the strategy that describes the vision and goals that should be realized through quantum technology, as well as policies and implementation plans for the practical and industrialization of quantum technology to achieve these goals. On the other hand, against the background of the remarkable progress in quantum technology, the situation surrounding Japan has been changing drastically, with each country formulating national strategies and international collaboration becoming more active. To respond quickly to this change, Japan hass developed a new document titled "Promotion Measures for the Development of Quantum Industries," in April this year. This is a report of measures to strengthen and complement the Japan's three strategies toward the 2030 goals.

In this report, a new perspective, "Globalization" is added to the three existing perspectives, "Collaboration", "Incubation", and "Accessibility". We have strengthened our efforts based on these four perspectives in an integrated manner.

We believe that we are entering a phase of utilizing quantum technology and international collaboration between like-minded countries as the key for further development. To further promote such international collaboration, we have sorted out various issues that we are facing and have clarified points that need to be strengthened.

We have also been strengthening Quantum Technology Innovation Hubs, consisting of 11 research centers in Japan. One of the strengthened hubs, G-QuAT, was set up as a department in AIST in July 2023 and will be fully launched after the completion of the main building in March 2025. In G-QuAT, various types of quantum computers will be actively developed through international competition and collaboration. The government of Japan strongly supports G-QuAT by imposing budgets, 32 billion yen at FY2022 and 30 billion yen at FY2023.

PL-02-02

# Australia's National Quantum Strategy

**Nicola Powell**

*Australian Government*

## Biography

Ms Nicola Powell manages Australian Government Quantum Engagement, within the Department of Industry, Science and Resources, covering domestic and international engagement. Ms Powell has 17 years' experience in policy development for the Australian Government, covering a wide range of policy areas including Medicine Regulation, Hospitals, National Security, Environment Protection, and Quantum. She also has over ten years' experience in private enterprise in Australia, mostly in the advertising industry.

## Abstract

The National Quantum Strategy, released in May 2023, is the Australian Government's plan to grow the quantum industry in Australia. The strategy sets out a long-term vision for how Australia will maximise the opportunities quantum technologies present, capitalising on prescient public investment and Australia's strong foundation in research and innovation, built on Australian talent. This presentation will showcase recent quantum developments in Australia under the National Quantum Strategy, outline Australia's quantum capabilities, and highlight opportunities for international partnerships with the Australian quantum sector.

PL-02-03

# Canada's Quantum Ecosystem and the National Quantum Strategy (NQS)

**Michael Rosenblatt**

*Director of the Federal Science and Technology Policy Directorate and National Quantum Strategy (NQS)*

## Biography

Michael Rosenblatt is the Director of the National Quantum Strategy (NQS) Secretariat in Innovation, Science and Economic Development Canada (ISED). His group is responsible for policy development and co-ordination of the implementation of the NQS, both domestically and internationally. Michael has a Ph.D. in Public Administration from Carleton University, a M.A. in Public Policy from McMaster University and an Honours B.A. from Wilfrid Laurier University in Political Science and Business.

## Abstract

This session will discuss Canada's quantum ecosystem and the National Quantum Strategy (NQS), providing a background on Canadian quantum researchers and companies, new developments, strengths and opportunities for engagement.

PL-02-04

# Denmark's Quantum Strategy

**Louise Lund Henneberg**

*Ministry of Foreign Affairs of Denmark*

## Biography

Louise is a Senior Advisor at the Danish Ministry of Foreign Affairs and team leader of the International Quantum Hub within the department for Techplomacy. The hub was established as part of Denmark's national strategy on quantum and focuses on the country's strategic international quantum partnerships. Louise and her team work to strengthen Denmark's bilateral, regional and multilateral engagement on quantum.

Before commencing this role, Louise was posted at the Permanent Representation of Denmark to the European Union where she served as a Danish delegate to EU Council working groups which covered cyber-diplomacy, hybrid threats and new technologies.

She joined the Ministry of Foreign Affairs of Denmark as a diplomat in 2017 and has worked on a number of policy areas including security and defense policy cooperation as well as humanitarian affairs.

Louise holds both a Master's degree and a Bachelor's degree in political science from Aarhus University. In 2015 she was a visiting graduate student at Columbia University's School of International and Public Affairs.

## Abstract

In a world full of unpredictability, crises and confrontation, technology can and must be a part of the solution. Quantum technology of the future will be able to perform calculations and measurements that are impossible with today's technology and it has the potential of delivering solutions to some

of today's global challenges.

Denmark aims to have one of the world's leading quantum research environments and to have the ability to effectively translate research into new, usable technology.

Since Niels Bohr's pioneering research, which laid the foundation for our understanding of quantum mechanics, some very strong research environments within quantum have been established in Denmark. Denmark remains at the forefront of quantum technology research and enjoys widespread international recognition. This presents a unique opportunity to unlock the immense potential of quantum technologies, not only in the realm of research but also in translating this knowledge into solutions that can benefit society, businesses, and national security, ultimately improving the lives of individuals worldwide.

In her intervention, Danish MFA Quantum Team Lead, Louise Lund Henneberg, will present the Danish national quantum strategy and the unique Danish ecosystem as well as the inherent international outlook that underpins Danish quantum policy.

PL-02-05

# EU Quantum Strategy

**Oscar Diez**

*European Commission*

## Biography

Dr. Oscar Diez is the head of quantum technologies at the European Commission (EC), the executive branch of the European Union (EU). Previously, Dr. Diez was head of datacentre at the European Medicines Agency (EMA) in London. He holds a PhD in Computer Science from Universidad Politécnica in Madrid and a Master's degree in Open eGovernment from the University of Stockholm. He is also adjunct professor at IE University in Madrid.

## Abstract

This presentation explores the European Union's strategic approach to advancing quantum technologies, with a focus on quantum computing and HPC integration, but coverting all the quantum technologies pillars in the EU. It highlights the EU's quantum research, public investment, and infrastructure development, including key initiatives such as the Quantum Flagship, EuroHPC, EuroQCI and the Chips Act. The presentation covers the EU's efforts to bridge gaps in private investment, foster industry and academic collaboration, and create a roadmap for future growth.

PL-02-06

# German National Quantum Technology Program

**Oliver Pieper**

*Head of Division for Science and Technology*

## Biography

Oliver Pieper is Head of the Science and Technology Division at the Embassy of the Federal Republic of Germany Tokyo.
Previously, he was Deputy Head of Division at the German Federal Ministry of Education and Research (BMBF), where he was lead coordinator for co-operation with Ukraine and other countries.
Oliver studied physics at Humboldt University and holds a PhD in physics from the Technical University of Berlin. He gained experience as a scientist in international research projects and as a consultant in R&D funding.
He was also responsible for innovation policy issues at the BMBF and managed various programmes to promote knowledge and technology transfer.

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## Abstract

In 2018 the German Federal Goverment launched its first federal program for quantum technologies. Since then Germany is investing heavily into quantum technologies with the aim to be one of the global leaders in all three domains of the technology: quantum computing, quantum sensing and quantum communication. This is underscored by the second federal program for quantum technologies published in 2023. Through this program more than 2.2 Billion Euros will be invested into quantum technologies until 2026.

PL-02-07

# Quantum Delta NL: Building the Netherlands Quantum Ecosystem

**Jesse Robbers**

*Director Industry & Digital Infrastructure Quantum Delta NL*

## Abstract

Quantum Delta NL is a dynamic and innovative quantum technology ecosystem located in the Netherlands that strives to create significant societal impact through technological advancements. We connect people in the quantum field and beyond, providing opportunities to learn, collaborate, and achieve more together.

Our ecosystem is built around three catalyst programs - quantum computing and simulation, national quantum network, and quantum sensing applications - and tied together with four action lines - research and innovation, quantum ecosystem, human capital, and societal impact.

Although the Netherlands is a small country, it possesses significant expertise and advanced facilities in the realm of quantum technology. The nation's distinct knowledge and innovation landscape is primarily supported by five specialized - yet interconnected - innovation hubs: QDNL Delft, QDNL Amsterdam, QDNL Leiden, QDNL Eindhoven, and QDNL Twente.

PL-02-08

# UK's Quantum Strategy

**Tom Newby**

*Department for Science, Innovation and Technology*

## Biography

Tom Newby is the Head of the Office for Quantum Technologies in the UK government's Department for Science, Innovation and Technology. In this role he oversees the implementation of the UK's national quantum strategy. Tom has worked on technology policy and strategy in various roles in the centre of the UK government and in Ofcom, the UK's communications regulator. Before his current role he was Head of Spending Strategy in the UK's finance ministry (the Treasury).

## Abstract

Tom Newby will give an introduction to the UK's quantum ecosystem and National Quantum Strategy published in March 2023.
Expect to hear about;
- the UK National Quantum Strategy, goals and missions
- what the UK has invested so far in Quantum technologies
- what the UK is doing internationally to collaborate on quantum technologies
- UK success stories
- what the UK is prioritising going forward

PL-02-09

# Updates on U.S. National Quantum Strategy

**John Speaks**

*State Department East Asia and Pacific Regional Technology Officer*

## Biography

**John Speaks**, a career Foreign Service Officer with the U.S. Department of State, currently serves as the State Department's Regional Technology Officer for East Asia, based in Tokyo Japan.
From 2022-2024, he served as the Deputy Minister Counselor for Energy, Environment, Science, and Technology Affairs (EEST) at the U.S. Embassy in New Delhi. In this role he led Mission India in the launch and implementation of the landmark U.S.-India Initiative on Critical and Emerging Technology. He also partnered with the office of Special Presidential Envoy for Climate to launch the bilateral Climate Action and Finance Mobilization Dialogue. Mr. Speaks served as Acting EEST Minister Counselor from 2020-2022.
Mr. Speaks previously served as Head of the Economic Affairs Unit at the U.S. Embassy in Austria, Deputy Economic Counselor and Humanitarian Aid Coordinator at the U.S. Embassy in Turkey, Deputy Economic Counselor at the U.S. Embassy in Egypt and held diplomatic posts in El Salvador and Venezuela.
Before joining the Department of State, Mr. Speaks enjoyed a successful career in banking and finance serving as a Vice-President at JPMorgan Chase Bank and as Director of Internet Services for American Express.
Mr. Speaks is a graduate of Columbia University in New York. He is married with two children.

## Abstract

Under the National Quantum Initiative, launched in 2018, the United States is pursuing a whole-of-government to accelerate U.S. leadership in quantum information science (QIS). Across the government, agencies and departments are establishing centers and programs to foster QIS research

and development (R&D) in coordination with industry and the academic community.

The United States is making substantial investments in QIS R&D to explore a wide range of applications and nurture a culture of discovery. As the development of QIS technologies evolves, The U.S. recognizes it is a critical time to develop the scientific knowledge, infrastructure, ecosystem and workforce to create new applications for QIS-inspired technologies.

My remarks will provide examples of specific programs being undertaken to realize this vision.

PL-03-01

# Quantum physics in the macroscopic domain

**Vlatko Vedral**

*Oxford U*

## Biography

Vlatko Vedral (PhD and BSc at Imperial College) is a Professor of Quantum Information at the University of Oxford. He has published over 400 research papers on various topics in quantum physics and quantum computing and is one of the Clarivate Highly Cited Researchers. He has given numerous invited plenary and public talks during his career. These include a specialised talk at a Solvay meeting (2010) and a popular one at the International Safe Scientifique (2007). He was awarded the Royal Society Wolfson Research Merit Award in 2007, the World Scientific Medal and Prize in 2009, the Marko Jaric Award in 2010 and was elected a Fellow of the Institute of Physics in 2017 and a member of the European Academy of Sciences in 2020. He has held many visiting professorships, among which are those held at the Universities of Vienna and Belo Horizonte, the Perimeter Institute in Canada and the ISI in Turin. He is consulting the World Economic Forum on the Future of Computation. Vlatko is the author of 4 textbooks and 2 popular books ("Decoding Reality" and "From Micro to Macro").

## Abstract

Many macroscopic phenomena rely on the laws of quantum physics. The solid-state physics, for instance, started with the realization that both electrons and vibrations have to be treated quantum mechanically to even begin to be able to understand the thermodynamical behaviour of many-body systems. A growing body of evidence now suggests that living systems too could be utilising quantum coherence, superpositions, and even, in some cases, quantum entanglement to perform specific tasks with higher efficiency. However, it is an exciting open question to what degree quantum effects can be maintained and controlled at the macroscopic

level. This is interesting not just for our quest to realise scalable quantum computers, but also for engineering special-purpose programmable nano-machines.
I will explain the basics of witnessing entanglement and I will put this into the context of our present understanding of macroscopic quantum phenomena. I will then present the single molecule spectroscopy experiments we are currently undertaking in our laboratory to obtain a better understanding of quantum effects in complex (bio)molecules. This will include our recent observation of the vacuum Rabi splitting in a living bacterium strongly coupled with the electromagnetic field as well as living tardigrades coupled to a superconducting qubit. I will also discuss how these experiments can be scaled-up, as well as how we can design artificial and hybrid biomimetic structures that capture the underlying fundamental quantum behavior of complex systems. Gravity may well be the only remaining frontier as far as quantisation is concerned. The fundamental question underpinning all this is: will quantum physics ultimately be superseded in the macro domain, or will it prove to be a universal description of all the known phenomena?

PL-03-02

# QuEra's path to fault-tolerant quantum computers

**Sergio Cantu**

*QuEra*

## Abstract

PL-04-01

# Q-STAR's initiatives for building a quantum ecosystem

**Taro Shimada**

*Quantum STrategic industry Alliance for Revolution(Q-STAR)*

## Biography

TARO SHIMADA
Chair of the Board
Quantum STrategic industry Alliance for Revorution
Representative Director
Corporate Officer, President and Chief Executive Officer, Toshiba Corporation

Taro Shimada joined Toshiba in October 2018 as Corporate Digital Business Chief Strategy Officer, and in April 2019 became Chief Digital Officer, responsible for Toshiba's digital transformation and for strategic business creation and promotion.
He was appointed CEO & Representative Director of Toshiba Data Corporation in February 2020, and President and CEO of Toshiba Digital Solutions Corporation in April 2020.
In March 2022, Mr. Shimada was appointed to take the reins at Toshiba, as President & CEO, and Corporate Officer, President & CEO in December 2023.

Mr. Shimada's diverse experience in hardware development includes commercial aircraft; process consultation for industry; and product life cycle management. An expert in factory automation and digitization, he has advised many of Japan's leading manufacturers. He is also an advisor to the Robot Revolution & Industrial IoT Initiative and the IoT Acceleration Lab, and has contributed to Industrie 4.0 in Germany and Connected Industries in Japan.

Mr. Shimada began his career in1990, working on aircraft design at ShinMaywa Industries Ltd. In 1999 he joined Structural Dynamics Research Corporation, a part of Siemens, which led to a series of progressively senior posts in Japan and at Siemens HQ in Germany. Prior to joining Toshiba, he was Executive Operating Officer at Siemens K.K. Mr. Shimada has been a guest professor at Otemon Gakuin University in Osaka, Japan, since April 2020. In May 2022, he was appointed Chairman of Q-STAR (Quantum STrategic industry Alliance for Revolution), a consortium that promotes business creation with quantum technologies.

Mr. Shimada relaxes by playing the drums, and enjoys all genres of music.

**Abstract**

With the rapid advancement of quantum technologies, many countries are developing national strategies and promoting international collaboration, moves that are fostering significant progress in building quantum ecosystems. In this presentation, I will explore the latest trends in quantum technology in Japan and worldwide. I will also highlight Q-STAR's key activities in 2024, and look at our efforts to establish robust quantum ecosystems, promote international standardization, and strengthen global partnerships. Finally, I will outline Q-STAR's future plans and the crucial role we aim to play in shaping the future of quantum technology.

PL-04-02

# Latest update from QIC

**Lisa Lambert**

*QIC*

## Abstract

PL-04-03

# Latest update from QuIC

**Thierry Botter**

*QuIC*

## Biography

Dr. Thierry Botter is a successful industry executive, and an expert in the area of quantum technologies. He is the Executive Director of the European Quantum Industry Consortium (QuIC), a pan-European industry association with nearly 200 members and affiliates dedicated to supporting and strengthening quantum companies on the global stage. He is also a long-standing contributor on quantum technologies at the World Economic Forum and serves as an advisor on various councils. Dr. Botter previously held several leadership positions at Airbus, including deputy-Head of Airbus' cross-divisional Central Research and Technology organisation. He also served as a member of the first strategic advisory board for the European Commission's Quantum Flagship. Dr. Botter holds a PhD in physics from the University of California, Berkeley, and a Master's degree in aerospace engineering from the University of Illinois at Urbana-Champaign.

## Abstract

QuIC is Europe's largest quantum-dedicated industry body, with nearly 200 members from across the continent and links to the rest of the world. The association cultivates collaborative work between its members on key foundational elements of the global quantum economy, such as standardisation, funding and intellectual property protection. QuIC also facilitates extensive networking, growth and outreach with its global industry showcase, Q-Expo, and its webinar series, Q-Wave. During the presentation, I will provide an overview of the association, its many activities, and present perspectives on links and opportunities between the Japanese Quantum ecosystem and the European quantum industry.

PL-04-04

# QED-C Overview: Looking back and looking ahead

**Celia Merzbacher**

*QED-C*

## Biography

Dr. Celia Merzbacher is Executive Director of the Quantum Economic Development Consortium (QED-C), a global consortium managed by SRI International that aims to enable and grow the quantum industry. Dr. Merzbacher has more than two decades of experience as a leader of large multidisciplinary partnerships and programs at the intersection of government and industry. She is on the CSIS Commission on U.S. Quantum Leadership and is U.S. Co-Chair of the Quad Investors Network's Quantum Center of Excellence. She also serves as an advisor to several quantum research organizations. Previously, Dr. Merzbacher was Vice President for Innovative Partnerships at the Semiconductor Research Corporation. In 2003-2008, she was Assistant Director for Technology R&D in the White House Office of Science and Technology Policy and Executive Director of the President's Council of Advisors on Science and Technology. Dr. Merzbacher is a Fellow of the AAAS and served as Chair of the National Materials and Manufacturing Board of the National Academies of Science, Engineering and Medicine and on the Boad of Directors of ANSI.

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## Abstract

The Quantum Economic Development Consortium (QED-C®) is a global consortium of stakeholders that aims to enable and grow the quantum industry. The consortium was established as part of the US National Quantum Initiative (NQI) and is supported by its more than 250 members and by the National Institute of Standards and Technology (NIST) in the US Department of Commerce. QED-C is focused on identifying gaps in enabling technologies, supply chains, workforce, standards and policies

and developing strategies for filling those gaps. To achieve its goals, QED-C has published reports on the use cases for quantum technologies in various sectors such as energy, finance, transportation and logistics, navigation, and biomedicine. International collaboration is a centerpiece of QED-C. Nearly one-third of corporate members are headquartered outside the United States and all members are seeking to connect globally with customers, suppliers, and collaborators. QED-C seeks to remove barriers to collaborations between Japan and the United States by strengthening linkages between companies and with government agencies on both sides of the Pacific.

PL-04-05

# Developing the global quantum ecosystem

**Jonathan Legh-Smith**

*UKQuantum*

## Biography

**Biography for Jonathan Legh-Smith MBE, Executive Director, UKQuantum**
**jonathan.legh-smith@ukquantum**

Jonathan Legh-Smith is Executive Director for UKQuantum, the association for the UK's quantum industry. Jonathan is responsible for the strategic direction of the association and representing the interests of UKQuantum members nationally and internationally. Jonathan is also a member of the UK National Quantum Technologies Programme Strategic Advisory Board, the National Quantum Computing Centre Technical Advisory Group and NPL's Quantum Metrology Institute Advisory Board.

Jonathan has extensive experience as an R&D and Innovation Executive, covering policy, strategy and programme management. Previously, Jonathan was Principal, Scientific Affairs for BT, and led engagement with national research & innovation priorities including Quantum Technologies, Future Telecoms and Cyber-Physical Infrastructure. He directed BT's Strategic Research programme for over 10 years along with BT's academic and industrial research partnerships; he was also BT's Head of Standards. Jonathan was awarded an MBE for services to science & technology in 2024.

LinkedIn: https://www.linkedin.com/in/jonathan-legh-smith-6300877/

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## Abstract

It is widely understood that international collaboration is essential for the development and success of the quantum industry. There is already strong

collaboration between governments, industry and academia. This talk will consider what further action can be taken to form a Global Quantum Ecosystem.

# Abstracts

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| **PL** Plenary Sessions | Opening, Government Policy on Quantum Science and Technology, Keynote, Global Quantum Ecosystem, Quantum×AI, Standardization ~ De facto and De jure for Industrialization ~ |
| **CP** Quantum Computing Track | QC with Ions, Atoms and Photons, Semiconductor QC, Superconducting QC, Industrialization of QC, Quantum Annealing, Near-term Quantum Computing, Toward FTQC, Quantum Algorithms and Foundation |
| **SE** Quantum Sensing Track | Solid-State Q. Sensors (1) 2D, SiC / Japan-Germany Diamond NV Collaboration Session Part 1*, Solid-State Q. Sensors (2) Japan-Germany Diamond NV Collaboration Session Part2*, Quantum Optical Sensing*, Quantum Life Science -Impact of nano-scale molecular structures in Living and Eco-Systems for Electron's Quantum behaviours-*,Quantum Life Science -Medical Applications of Quantum Techniques-*, Atom Ion Sensing, Quantum MRI<br>* Q-LEAP 7th IFQMS Joint Session |
| **CC** Quantum Cryptography & Communication Track | Quantum Key Distribution and Its Network, Satellite Quantum Communication, Quantum Communication for Computation, Quantum Network, Social Implementation of Quantum Communication, Quantum Cryptography: Present and Prospects |
| **MA** Special Session | Materials for Future Quantum Information Technologies |

# Developing modular microwave trapped-ion quantum computers for operation with millions of qubits

**Winfried K. Hensinger**

*Sussex Centre for Quantum Technologies, Department of Physics and Astronomy, University of Sussex / Brighton BN1 9QH, United Kingdom/Universal Quantum Ltd, Brighton BN1 6SB, UK. 3*

## Abstract

Microwave technology poses a significant opportunity to scale trapped ion quantum computers to system sizes that support utility scale quantum computation within the fault-tolerant regime.

I will present progress on making microwave quantum gates faster with errors much below the fault-tolerant threshold by creating much larger magnetic field gradients. We have successfully developed a new generation of ion microchips capable of generating large magnetic field gradients in excess of 100 T/m. I will show progress on realizing high-fidelity gates with these new chips.

Current quantum computers can only operate with around 100 quantum bits while most disruptive industry applications would require quantum computers that can process millions of quantum bits. I will discuss a recent achievement, the demonstration of electric fields links between ion microchips as well as successful transport of ion qubits between microchips that should enable the construction of quantum computers with millions of quantum bits. I report the demonstration of a quantum matter-link in which ion qubits are transferred between adjacent quantum computer modules [1]. Ion transport between adjacent modules is realised at a rate of 2424 $s^{-1}$ and with an infidelity associated with ion loss during transport below $7 \times 10^{-8}$.

Furthermore, I will show that the link does not measurably impact the phase coherence of the qubit.

Finally I will discuss the enhanced connectivity in our transport based trapped ion quantum computer and discuss the creation of a decoder enabling transversal logical quantum gates.

I will also discuss the path forward to build practical trapped ion quantum computers. This includes the underlying research within our research group at the University of Sussex; an engineering focussed approach to construct practical machines at spin-out company Universal Quantum; work with future quantum computing users to develop applications and use cases in order to fast track the demonstration of disruptive industry applications.

[1] A High-Fidelity Quantum Matter-Link Between Ion-Trap Microchip Modules, M. Akhtar, F. Bonus, F. R. Lebrun-Gallagher, N. I. Johnson, M. Siegele-Brown, S. Hong, S. J. Hile, S. A. Kulmiya, S. Weidt & W. K. Hensinger, A high-fidelity quantum matter-link between ion-trap microchip modules. Nature Communications 14, 531 (2023)

CP-01-02

# Scaling quantum computing with a light-matter hybrid architecture

**Niccolo Somaschi**

*Quandela*

## Abstract

In the talk I will present a novel quantum computing approach that harness a mixture of light and matter based qubits, to optimise on the bottleneck and roadblocks associated to fully-light or matter approaches.
With quantum computers scalability associated to the ability to network remote qubits at high speed, the presented architecture provides a vialble path with strong optimization of resources.

CP-01-03

# A cold-atom quantum computer

**Sylvain de Léséleuc**

*IMS / RIKEN*

### Abstract

I will present the Cold-Atom Quantum Computer project being run within the Moonshot Goal 6 program "Fault-tolerant quantum computers". I will introduce the vision on how our R&D efforts are organized to push the performance of cold-atom-based platform. I will then describe the large-scale effort to realize a quantum computer prototype established collaborations accross Japan and abroad, as well as more specific research lines pushing along promising and exciting directions.

CP-02-01

# Scaling up quantum computing with silicon quantum dots

**Mark A. I. Johnson**

*Quantum Motion Technologies*

## Abstract

Spin qubits hosted in silicon-based devices have excellent initialisation, control and readout fidelities in small scale demonstrations [1-3]. A silicon foundation lends itself to large-scale manufacturing [4-6], where in principle millions of qubits can be integrated into a single chip, however this is not readily achievable using the same processes commonly used for current spin qubit devices. Moreover, the translation of modern designs to commercially available processes is nontrivial and requires careful consideration of the design constraints and parameters available. This talk will present Quantum Motion's effort to develop reproducible and scalable silicon spin qubits with a focus on mass characterisation to increase cryogenic measurement throughput.

CP-02-02

# Error dynamics during coherent electron spin shuttling

**Natalie D. Foster**

*Sandia National Laboratories*

## Abstract

Quantum information transport over micron to millimeter scale distances is critical for the operation of practical quantum processors based on spin qubits. One method of achieving long-range entanglement is by coherent electron spin shuttling through an array of silicon quantum dots. In order to execute high fidelity shuttling operations required to link millions of qubits on a processor, it is essential to understand the dynamics of qubit dephasing and relaxation during the shuttling process in order to mitigate noise sources before they cause errors. However, errors arising after implementing a large number of repeated shuttles are not yet well documented. We probe decay dynamics contributing to dephasing and relaxation of a singlet-triplet qubit during coherent spin shuttling over many $N$ repeated shuttle operations. We find that losses are dominated by magnetic dephasing for small $N < 10^3$ and by incoherent shuttle errors for large $N > 10^3$. Additionally, we estimate a competitive shuttle error rate below $1 \times 10^{-4}$ out to at least $N = 10^3$, representing an encouraging figure for future implementations of spin shuttling to entangle distant qubits.

CP-02-03

# Toward large-scale integration of silicon spin qubits with low variability

**Kimihiko Kato**

*National Institute of Advanced Industrial Science and Technology (AIST)*

## Abstract

Silicon spin qubits hold promise for realizing large-scale integrated arrays, thanks to advancements in manufacturing technologies in silicon integrated circuits. Research on silicon qubits has historically focused on initial demonstrations using small-scale structures with a few quantum dots; however, since around 2018, structures for large-scale integration have been proposed, and manufacturing and demonstrations have started. At the same time, the importance of research in performance variability is rapidly recognized in preparation for large-scale qubit operations.
To suppress the performance variability, eventually, it will be necessary to identify its source and develop appropriate processes. However, even preliminary quantitative evaluation of variability is not straightforward. For instance, qubit devices typically consist of multi-gate structures to control potential wells and barriers. Therefore, electrostatic coupling among gates can complicate property evaluations for each gate stack. Additionally, proposing structures that are tolerant of manufacturing variations and minimize their impact on performance variation can also be beneficial.
Our research team at AIST works on device development and demonstrations aiming for future applications in large-scale arrays, focusing on the fin-shaped silicon spin qubit structure using a silicon-on-insulator (SOI) substrate. From the perspective of variation, we examine the impact of work function variation, as one instance to understand the effects of electrostatic coupling in multi-gates. Through this study, we propose a method to mitigate this impact while improving the accuracy of threshold-voltage evaluation in each gate stack. We are also exploring innovative substrate and micro-magnet structures to achieve qubits capable of

suppressing performance variation even under certain dimensional non-uniformity. We would like to present our recent research activities, including these topics, in the presentation.

CP-03-01

# Engineering strategies to enable flexible supercFonducting qubits fabrication

**Floris Brulleman**

*Quantware*

## Abstract

As superconducting quantum circuits grow increasingly complex, ensuring reliable and scalable fabrication becomes critical to advancing quantum hardware. In this presentation, we discuss key engineering strategies that enable our fabrication platform to meet these challenges. A key feature of our platform is that it is made available to the community, allowing for chip design using our established fabrication processes. This open-access model provides researchers and developers with the flexibility to implement and test their quantum architectures while ensuring high-quality and high-yielding manufacturing outcomes.

The core of the presentation delves into how we optimize Josephson junctions, ensuring cross-customer compatibility while maintaining precise control over critical parameters. We also present coherence results, focusing on T1 and T2 as implemented in realistic quantum processors, showcasing our capability to meet the demands of practical quantum computing applications. As our last topic, we delve into post-fabrication methods, such as targeting resonators and fine-tuning designs, which allow us to further refine device performance after initial fabrication.

CP-03-02

# Foundry service for superconducting digital and quantum circuits in G-QuAT/AIST

**Mutsuo Hidaka**

*AIST*

## Abstract

National Institute of Advanced Industrial Science and Technology (AIST) established a new center regarding quantum technologies whose name is Grobal Research and Development Center for Business by Quantum-AI Technology (G-QuAT). G-QuAT possesses a clean room for superconducting devices. The clean room is Superconducting Quantum Circuit Fabrication Facility (Qufab). Qufab took over superconducting circuit fabrication technologies which have been developed and implemented many circuits for more than 40 years in AIST and other Japanese institutes. Up to now, supply destinations of Qufab devices were limited to several collaborated institutes with AIST. October 2024, Qufab started open foundry service to wide range of users. Expected users are domestic and international, public and private institutes. Both research and commercial uses are acceptable. Superconducting digital circuits which consist of four Nb layers, one Nb/Al-$AlO_x$/Nb Josephson junction layer, one Mo resistance layer and planarized $SiO_2$ between the metal layers are fabricated for the first foundry service and multiple users share one 4-inchi wafer. Because Qufab will stop from January to March in 2025 by replacing several equipment, Qufab foundry start in full swing will be spring 2025. Quantum circuits will be added to the foundry service in the future.

CP-04-01

# Toward industrialization of quantum computing technology

**Masayuki Shirane**

*NEC*

## Abstract

CP-05-01

# Technical update: Annealing quantum computing's rapid progress

**Emile Hoskinson**

*D-Wave*

## Abstract

Annealing quantum computing is undergoing rapid technological progress in the scientific domain, with magnetic materials simulation [Computational supremacy in quantum simulation (arXiv:2403.00910)], and in the large-scale commercial optimization domain, with powerful new hybrid quantum-classical solvers. Here we describe the use of D-Wave annealing quantum computers to simulate magnetic materials with a variety of lattice topologies. We first reproduce expected coherent quantum dynamics in small-scale problems that can be simulated classically, then scale to problems beyond the reach of classical computing. We describe the powerful new coherent quantum annealing capability of D-Wave annealing quantum computers now available to customers that makes this possible. We give a preview of newer advanced features on the horizon, which we expect will enable excited state control within quantum annealing processors, potentially opening up powerful new approaches to quantum computation.

CP-05-02

# Localization detection based on quantum dynamics

**Kazue Kudo**

*Ochanomizu University*

## Abstract

In disordered quantum many-body systems, strong disorder can lead to localization. Recent advancements in quantum technologies have enabled the probing of such localization phenomena through quantum dynamics. This work explores the observation of localization in a quantum spin chain. Numerical simulations using exact diagonalization demonstrate that magnetization and twist overlap, measured after short evolution, are promising indicators of disorder-induced localization. Furthermore, localization can be detected experimentally on a noisy quantum computer. While both observables can be easily measured by examining qubits at the end of the time evolution, computations reveal that twist overlap is more susceptible to noise-induced errors than magnetization. Despite this, twist overlap offers greater insight into the system's behavior than magnetization alone.

CP-05-03

# Beyond quantum inspired annealing for quadratic unconstrained binary optimization

**Matthieu Parizy**

*Q-STAR*

## Abstract

We have developed a method to extend the functionality of Ising machines such as quantum and digital annealers, which currently have an energy function limited to a binary-quadratic form. The proposed method utilizes auxiliary variables dependent on the decision variables of the problem to be solved so that it can be accelerated by hardware parallel processing. Auxiliary variables add third-order or higher terms or rectified linear unit-type nonlinear functions to the binary-quadratic energy function of Ising machines, modifying the value of the energy difference resulting from the reversal of the decision variable. To enable parallel computation, the computation of the energy change uses information that can be accessed locally by the decision neurons. We confirmed that the proposed method works for the 0/1 linear knapsack problem, the quadratic knapsack problem, the 3-SAT problem, and the random 3-XORST problem.

CP-06-01

# Design of quantum-HPC hybrid platforms leveraging supercomputers

**Miwako Tsuji**

*RIKEN*

### Abstract

We started developing a quantum-HPC hybrid platform last year. In this talk, we present several prototype implementations and the preliminary results of our experiments. Additionally, we outline the design of the quantum-HPC hybrid platform, which was refined through these experiments.
Our design maximizes supercomputers' performance efficiency and provides flexible solutions tailored to support a wide range of quantum-HPC hybrid applications. By leveraging supercomputers' capabilities, we aim to create a platform that seamlessly integrates quantum and HPC computing for various computational tasks.

CP-06-02

# Development of superconducting quantum computer at QIQB, Osaka University

**Kazuhisa Ogawa**

*Osaka University*

## Abstract

In the last decade, there has been a worldwide flurry of activity in the development of superconducting quantum computers. Recently, systems with a scale of around 100 qubits have been announced, and research for further large-scale integration is underway. In Japan, RIKEN, Fujitsu, and Osaka University have announced the development of superconducting quantum computers that can be controlled from the cloud, independently and successively, in 2023. All of these systems use the same 64-qubit chips developed by RIKEN, and the microwave control devices that use technology developed by Osaka University. The RIKEN and Osaka University systems also use a cloud system developed by Osaka University and others. In this talk, we will briefly explain the structure and performance of the 64-qubit superconducting quantum computer at QIQB, Osaka University, and then report on our recent research efforts using the system.

CP-06-03

# Toward open-source software for quantum computing

**Stefano Carrazza**

*University of Milan*

### Abstract

We present Qibo, an open-source quantum computing framework offering a full-stack solution for efficient deployment of quantum algorithms and calibration routines on quantum hardware. Quantum computers require compilation of high-level circuits tailored to specific chip architectures and integration with control electronics. Our framework tackles these challenges through Qibolab, a versatile backend that interfaces with a wide range of electronics -both commercial and open-source- for seamless program execution on quantum devices. Moreover, frequent calibration is essential for maintaining quantum computers in an operational state. Qibocal simplifies this process, providing a hardware-agnostic interface that automates calibration routines across supported platforms, complete with advanced reporting tools. We will demonstrate our software suite on platforms based on superconducting qubit technology, highlighting performance benchmarks using different electronics. The ease of integrating new hardware drivers makes Qibo particularly valuable for labs aiming to control their own self-hosted quantum systems.

CP-07-01

# Constant overhead fault-tolerant quantum computation in realistic physical systems

**Juan Pablo Bonilla Ataides**

*Harvard University*

## Abstract

Quantum low-density parity-check (qLDPC) codes can achieve high encoding rates and good code distance scaling, providing a promising route to low-overhead fault-tolerant quantum computing. However, the long-range connectivity required to implement such codes makes their physical realization challenging. Here, we propose a hardware-efficient scheme to perform fault-tolerant quantum computation with high-rate qLDPC codes on reconfigurable atom arrays, directly compatible with recently demonstrated experimental capabilities. Our approach utilizes the product structure inherent in many qLDPC codes to implement the non-local syndrome extraction circuit via atom rearrangement, resulting in effectively constant overhead in practically relevant regimes. We prove the fault tolerance of these protocols, perform circuit-level simulations of memory and logical operations with these codes, and find that our qLDPC-based architecture starts to outperform the surface code with as few as several hundred physical qubits at a realistic physical error rate of 1e–3. We further find that less than 3000 physical qubits are sufficient to obtain over an order of magnitude qubit savings compared to the surface code, and quantum algorithms involving thousands of logical qubits can be performed using less than 105 physical qubits. Our work paves the way for explorations of low-overhead quantum computing with qLDPC codes at a practical scale, based on current experimental technologies.

CP-07-02

# Early fault-tolerant quantum computation in practice

**Nobuyuki Yoshioka**

*University of Tokyo*

## Abstract

In this talk, we first discuss the current status in quantum computing, including the achievements and limitations of NISQ devices and advancements in quantum error correcting experiments and theory. Then, we proceed to future perspective in practical quantum advantage in condensed matter physics, quantum chemistry, and so on. We further discuss crutial steps to be made in software, middleware layers.

CP-07-03

# Quantum error correction below the surface code threshold

**Michael Newman**

*Google Quantum AI*

### Abstract

In this talk, I'll present an overview of our demonstration of quantum error correction below the surface code threshold (arXiv:2408.13687). Each time we increase the code to correct one extra error, the logical error rate is reduced by a factor of two. This culminates in a 101-qubit surface code with a logical error per syndrome extraction cycle of 0.143%. I'll touch on some promising developments (e.g. improved device performance, stability, leakage mitigation, real-time error correction) along with some of the challenges (e.g. an error floor around $10^{-10}$) as we continue to scale.

CP-08-01

# Classical topology & quantum complexity

**Tamara Kohler**

*Stanford University*

## Abstract

I will present work studying the complexity of a classic problem in computational topology, the homology problem: given a description of some space decide whether or not it contains a hole. The types of space I will consider are clique complexes of graphs, where a clique complex is a simplicial complex defined by the cliques of a graph. This is motivated by the practical applications of topological data analysis (TDA). The setting and statement of the homology problem are completely classical, yet I will show that the complexity is characterized by quantum complexity classes. This result provides some suggestion that the quantum TDA algorithm [LGZ16] cannot be dequantized. More broadly, it opens up new possibilities for quantum advantage in topological data analysis.

CP-08-02

# Clustering of conditional mutual information and quantum Markov structure at arbitrary temperatures

**Tomotaka Kuwahara**

*RIKEN Center for Quantum Computing*

## Abstract

Recent investigations have unveiled exotic quantum phases that elude characterization by simple bipartite correlation functions. In these phases, long-range entanglement arising from tripartite correlations plays a central role. Consequently, the study of multipartite correlations has become a focal point in modern physics. In these, Conditional Mutual Information (CMI) is one of the most well-established information-theoretic measures, adept at encapsulating the essence of various exotic phases, including topologically ordered ones. Within the realm of quantum many-body physics, it has been a long-sought goal to establish a quantum analog to the Hammersley-Clifford theorem that bridges the two concepts of the Gibbs state and the Markov network. This theorem posits that the correlation length of CMI remains short-range across all thermal equilibrium quantum phases. In this work, we demonstrate that CMI exhibits exponential decay concerning distance, with its correlation length increasing polynomially in relation to the inverse temperature. While this clustering theorem has previously been established for high temperatures devoid of thermal phase transitions, it has remained elusive at low temperatures, where genuine long-range entanglement is corroborated to exist by the quantum topological order. Our findings unveil that, even at low temperatures, a broad class of tripartite entanglement cannot manifest in the long-range regime. To achieve the proof, we establish a comprehensive formalism for analyzing the locality of effective Hamiltonians on subsystems, commonly known as the 'entanglement Hamiltonian' or 'Hamiltonian of mean force.' As one outcome of our analyses, we enhance the prior clustering theorem concerning

bipartite entanglement. In essence, this means that we investigate genuine bipartite entanglement that extends beyond the limitations of the Positive Partial Transpose (PPT) class.

CP-08-03

# Quantum communication beyond QKD: Position-based cryptography

**Harry Buhrman**

*Quantinuum*

## Abstract

On 20 July 1969, millions of people held their breath as they watched, live on television, Neil Armstrong set foot on the Moon. Yet Fox Television has reported that a staggering 20% of Americans have had doubts about the Apollo 11 mission. Could it have been a hoax staged by Hollywood studios here on Earth? Position-based cryptography may offer a solution. This kind of cryptography uses the geographic position of a party as its sole credential. Normally digital keys or biometric features are used.
A central building block in position-based cryptography is that of position verification. The goal is to prove to a set of verifiers that one is at a certain geographical location. Protocols typically assume that messages cannot travel faster than the speed of light. By responding to a verifier in a timely manner one can guarantee that one is within a certain distance of that verifier.  It was shown that position-verification protocols only based on this relativistic principle can be broken by attackers who simulate being at the claimed position while physically residing elsewhere in space.
Because of the no-cloning property of quantum information (qubits) it was believed that with the use of quantum messages one could devise protocols that were resistant to such collaborative attacks. Several schemes were proposed that later turned out to be insecure. In 2012 it was shown that also in the quantum case no unconditionally secure scheme is possible. However, many questions concerning the optimality of the attack remain open.
We will review the old results as well as some of the new sometimes very surprising connections with seemingly unconnected research areas such as holography, ADS/CFT correspondence, and classical primitives like

conditional disclosure of secrets (CDS), secure message passing (SMP), and functional analysis. We will also cover some of the recent proposals for implementing position verification protocols that are secure when the attackers have a limited amount of entanglement.

# Abstracts

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SE-01-01

# Spin defects in hBN for quantum sensing applications

**Jean-Philippe Tetienne**

*RMIT University*

## Abstract

Hexagonal boron nitride (hBN) has emerged as a promising material for quantum sensing, being host to a variety of optically addressable spin defects. In this talk, I will first present our work on the boron vacancy defect in hBN and show how it can be used for magnetic imaging and relaxometry-based sensing. I will then present results on a class of spin-half defects which emit at various wavelengths from the blue to near-infrared. I will discuss our current understanding of these spin-half defects, and present applications to omnidirectional magnetometry and radiofrequency sensing. Owing its van der Waals nature, hBN opens new opportunities for nanoscale sensing and integration into multi-functional devices.

SE-01-02

# Room-temperature photoelectrical detection of spins in silicon carbide

**Naoya Morioka**

*Kyoto University*

## Abstract

Optically addressable spins of point defects in semiconductors are a promising platform for quantum technologies such as quantum information technologies and quantum sensing. Silicon carbide hosts various spins with long coherence times even at ambient conditions. In addition to the electronic spin, the surrounding nuclear spins in the host material can couple to the electronic spin and play an important role as a quantum memory to store the quantum information and enhance the sensitivity of quantum sensors. Usually, these spins are read out optically by counting emitted photons. However, the photoelectrical detection of magnetic resonance (PDMR) technique allows the electrical spin readout by fabricating the spin detection electrodes on the semiconductor and reading out the spin-dependent photocurrent. The electrical detection method is particularly promising in SiC, a semiconductor with excellent electrical properties. High electronic device compatibility of SiC will enable on-chip integration of the quantum system with peripheral functionalities and the miniaturization of the SiC-based quantum devices. Also, electrical readout is expected to achieve superior spin detection sensitivity thanks to the easier control of the photoionized charge collection by the electric field compared to the optical detection, which suffers from limited photon collection due to the total internal reflectance in the high refractive index material. In this talk, we present our recent studies on high-resolution electrical detection of electronic spins of silicon vacancies and surrounding nuclear spins in SiC by the PDMR technique.

SE-01-03

# Creation of spin defects in wide bandgap semiconductors for quantum sensing

**Takeshi Ohshima**

*National Institutes for Quantum Science and Technology*

## Abstract

Spin defects in wide bandgap semiconductors are expected to be applied to qubits and quantum sensors. Negatively charged nitrogen - vacancy (NV) center in diamond is known as one of the most promising candidates for qubits and quantum sensors since photoluminescence from single NV center can be detected and its spin can be manipulated even at room temperature. Particle irradiation such as ions and electrons is a powerful tool to introduce such spin defects in wide bandgap semiconductors. In this talk, I will show the electron irradiation techniques to create ensemble NV centers for quantum sensing. The amounts of NV centers created by electron irradiation at elevated temperature are compared with those by room temperature irradiation followed by thermal annealing. Also, I will introduce the creation of multiple NV centers by the implantation of molecular ions which contain N atoms such as adenine and phthalocyanine ions. In addition, I will talk about the creation of negatively charged silicon vacancy (Vsi) in silicon carbide (SiC), which also acts as spin defects, using the particle beam writing (PBW) technique. PBW is a useful technique to create Vsi at certain locations. Therefore, we locally create Vsi in SiC devices and the local temperature and magnetic field induced by currents in SiC devices can be measured.

SE-02-01

# Quantum sensing at nanoscale enabled by diamond spin qubits

**Fedor Jelezko**

*Ulm University*

## Abstract

Synthetic diamond has recently emerged as a candidate material for a number of quantum applications, including quantum information processing and quantum sensing. In this talk, I will show how single nitrogen-vacancy (NV) colour centres can be created near the diamond surface and used as nanoscale sensors of electric and magnetic fields. I will also demonstrate novel dynamical decoupling techniques allowing to improve the sensitivity of diamond quantum sensors and discuss applications of small-scale quantum registers for nanoscale NMR. Applications of NV centres for hyperpolarisation of nuclear spins and application of optical spin polarisation in MRI will be presented.

SE-02-02

# Quantum sensor-enabled optical magnetic resonance microscopy

**Dominik Bucher**

*Technical University of Munich*

## Abstract

Nitrogen vacancy (NV) centers in diamond have emerged as a promising platform for nano- and microscale sensing. In my talk, I will demonstrate the capability of NV centers for microscale NMR microscopy. Unlike conventional magnetic resonance imaging (MRI), which typically relies on k-space sampling and magnetic field gradients for spatial encoding of nuclear magnetic resonance (NMR) signals, NV centers can directly translate local NMR signals into an optical signal.

In the first approach, we use a camera that enables real-space NMR imaging with micron-scale spatial resolution over a wide field of view. This novel optical NMR microscopy technique is capable of imaging NMR signals within a model microstructure, achieving a spatial resolution of approximately 10 μm over a field of view of $235 \times 150\ \mu m^2$. Each camera pixel captures a full NMR spectrum, providing comprehensive data on signal amplitude, phase, and local magnetic field gradients. [1]
In the second part of my talk, I will present a novel NV-readout scheme where we use a fast scanning laser spot to cancel common noise and enable few-pixel imaging without the need for a camera. [2]

The integration of optical microscopy with NMR opens new avenues for diverse applications in the physical and life sciences, such as imaging water and metabolic processes in single cells or tissue samples, studying battery

materials, or facilitating high-throughput NMR analysis.

[1] K. D. Briegel, N. R. von Grafenstein*, J. C. Draeger*, P. Blümler, R. D. Allert, D. B. Bucher. Optical Widefield Nuclear Magnetic Resonance Microscopy. https://arxiv.org/abs/2402.18239

[2] J. P. Leibold*, N. R. von Grafenstein*, X. Chen, L. Müller, K. D. Briegel, and D. B. Bucher. Time-space encoded readout for noise suppression and scalable scanning in optically active solid-state spin systems. https://doi.org/10.48550/arXiv.2408.14894

SE-02-03

# Potential of diamond quantum sensors based on spin-qubits of NV centers

**Mustuko Hatano**

*Department of Electrical Engineering*

## Abstract

Solid-state quantum sensors using diamond and SiC are expected to have various applications due to their fundamental possibilities such as wide dynamic range, operating temperature range, and high spatial resolution.

In the MEXT Q-LEAP quantum solid-state sensor flagship project, five academia, two national research institutes, and four companies have joined forces to develop solid-state quantum sensors from fundamental science to prototype applications in quantum physics, materials, and sensor systems.

In this talk, I would like to show the latest research topics of Q-LEAP, including high-quality quantum materials, high-sensitivity magnetometers, and compact sensor modules. Additionally, I will introduce sensor systems for biological/medical applications and battery/power electronics. Furthermore, I will discuss the expectations for a future "quantum leap" society based on quantum solid-state sensor technology.

SE-03-01

# Time-resolved photon antibunching in single molecules

**Gordon J. Hedley**

*School of Chemistry, University of Glasgow, Glasgow, U.K.*

## Abstract

Single molecule spectroscopy involves measuring objects one at a time, enabling conclusions to be drawn free from ensemble averaging effects or complex interdependencies. Measuring the light emitted by single molecules or nanoscopic objects also allows signatures of quantum behaviour such as photon antibunching to be observed. Conventional antibunching measurements record the intensity-weighted average of the photon statistics over the excited state lifetime, giving a single correlation curve. This allows limited insight into any fast (ps-ns) evolution of the system, thus information on how states form, move and interact is typically lost.

Here I will talk about our recent work using modern photon counting hardware to time-resolve photon statistics, down to times as short as ~50 ps, observing how the antibunching signature evolves during the molecule's excited state lifetime. This allows the fingerprints of state coupling and losses to be identified. The concept will be first explored with DNA origami, where a fixed number of, and position, of emitters is defined. I will then discuss these measurements in more complex nanoscopic aggregates, before applying the techniques to observations in single organic semiconducting polymer chains. Finally, I will talk about our latest research developing two-colour time-resolved photon antibunching measurements, where coupling between energetically different states can be explored.

This work has relevance to the photophysics of organic semiconducting materials, but also to the development of quantum optical measurements that can assess coherence and the quantum fidelity of excited states in polyatomic systems within the domain of quantum information science.

SE-03-02

# Theory of time-resolved optical spectroscopy with quantum entangled photons

**Yuta Fujihashi**

*The University of Electro-Communications*

## Abstract

Quantum light exhibits unique photon statistics and correlations absent in classical light. Harnessing these quantum properties allows selective excitation and precise measurements that cannot be performed in spectroscopic measurements using classical light such as lasers. With advances in quantum optical technology, there has been increased interest in the use of quantum light in nonlinear spectroscopic measurements of molecular systems. In these respects, applying entangled photons to time-resolved spectroscopy can open new avenues for unambiguously extracting information on dynamical processes in complex molecular and material systems.

We propose transmission measurement of frequency-entangled broadband photon pairs generated via parametric down-conversion with a monochromatic laser [1,2]. It is observed that state-to-state dynamics in the system under study are temporally resolved by adjusting the path difference between the entangled twin beams when the entanglement time is sufficiently short. The non-classical photon correlation enables time-resolved spectroscopy with monochromatic pumping.

Furthermore, we consider a quantum spectroscopy measurement method extending the above time-resolved quantum spectroscopy to a two-photon coincidence type [3]. We demonstrate that the photon number correlation enables the selective elimination of specific signal pathways in nonlinear spectra, which cannot be realized with classical coherent light. We anticipate that the proposed spectroscopy will help simplify the spectral interpretation of complex molecular and material systems comprising multiple molecules.

Finally, we discuss how time-resolved quantum spectroscopy can be

achieved using current photon detection technology [4].

[1] A. Ishizaki, *J. Chem. Phys*. **153**, 051102 (2020).
[2] Y. Fujihashi, K. Miwa, M. Higashi, A. Ishizaki, *J. Chem. Phys*. **159**, 114201 (2023).
[3] Y. Fujihashi, A. Ishizaki, and R. Shimizu, *J. Chem. Phys*. **160**, 104201 (2024).
[4] Y. Fujihashi, O. Iso, A. Ishizaki, and R. Shimizu, *in preparation*.

SE-03-03

# Quantum-enhanced measurements of molecular concentration and chirality using entangled photon pairs

**Korenobu Matsuzaki**

*RIKEN*

## Abstract

Quantum light, such as entangled photon pairs, is a special state of light that cannot be described by classical electrodynamics. Owing to its nonclassical properties, the use of quantum light can open up new possibilities for optical spectroscopy that are not achievable by classical light sources. In this study, we report the realization of ultrasensitive absorption spectroscopy with quantum-enhanced sensitivity using entangled photon pairs as the light source [1]. This novel approach allows us to obtain absorption spectra with a noise level suppressed below the shot-noise limit, which is a fundamental and unavoidable limit in conventional absorption spectroscopy. We apply the developed method to the absorption measurements of dye solutions containing two different kinds of dye species and demonstrate that the concentration of each dye molecule can be determined with precision beyond the limit of conventional absorption spectroscopy [1]. Furthermore, by utilizing circularly polarized entangled photons instead of linearly polarized ones, we show that molecular chirality measurements based on circular dichroism spectroscopy can also be performed with quantum-enhanced sensitivity [2].

[1] K. Matsuzaki and T. Tahara, *Nat. Commun.* **13**, 953 (2022).
[2] K. Matsuzaki and T. Tahara, *ACS Photonics* **11**, 1376 (2024).

SE-04-01

# Chiral induced spin selectivity effect in various biomolecular systems

**Suryakant Mishra**

*Los Alamos National Laboratory*

## Abstract

In this talk, I will discuss chiral-induced spin selectivity (CISS), recent advancements, and their applications across various fields of science.
My specific focus will be on the impact of the CISS effect in biomolecular systems and the critical role spin plays in charge transfer within these systems. One such system is multiheme cytochromes, located on the bacterial cell surface, where extracellular electron transfer processes enable microorganisms to gain energy by respiring solid redox-active minerals. Using techniques such as magnetic conductive probe atomic force microscopy, Hall voltage measurements, and spin-dependent electrochemistry of the decaheme cytochromes MtrF and OmcA from the metal-reducing bacterium *Shewanella oneidensis* MR-1, we have observed signatures of spin-selective electron transport through these extracellular conduits.

Finally, I will discuss the implications of understanding how spin-dependent interactions and magnetic fields can control electron transport across biotic–abiotic interfaces in both natural and biotechnological systems.

SE-04-02

# Structural basis for color tuning and ion selectivity in potassium-selective channelrhodopsins

**Hideaki Kato**

*The University of Tokyo*

## Abstract

Optogenetics is a groundbreaking experimental technique that allows scientists to control the membrane potential of cells, particularly neurons, using light. This method relies on light-responsive proteins called channelrhodopsins (ChRs), which are found in microorganisms and function as light-activated ion channels. Optogenetics has profoundly impacted neuroscience by enabling precise manipulation of neural circuits in the brain.

To advance optogenetic experiments and better understand brain function, researchers have discovered and engineered various types of ChRs with diverse properties. However, most ChRs developed so far fall into two categories based on the ions they transport: non-selective cation channels, which activate neurons, and $Cl^-$ channels, which inhibit them. While $Cl^-$ channels are useful for suppressing neuronal activity, their effectiveness is limited because the balance of $Cl^-$ inside and outside cells can fluctuate.

In 2021, scientists made a significant breakthrough by discovering potassium channelrhodopsins (KCRs), a new type of ChR that selectively transports $K^+$. KCRs are considered ideal tools for inhibiting neurons because they offer more stable and reliable control compared to $Cl^-$ channels. Unlike traditional potassium channels, KCRs have entirely different amino acid sequences and structural features, and the mechanism by which they specifically select $K^+$ ions was previously unknown.

In our research, we used cryo-electron microscopy to determine the structures of two newly discovered KCRs, HcKCR1 and HcKCR2. By combining these structural insights with electrophysiological and

computational analyses, we uncovered the molecular basis for why HcKCR1 and HcKCR2 absorb different wavelengths of light and how they selectively transport $K^+$. Additionally, we developed a mutant version of KCR, named KALI, which shows enhanced selectivity for $K^+$ and outperforms existing inhibitory optogenetic tools.

Our findings not only deepen the understanding of how KCRs function at a molecular level but also provide improved tools for neuroscientific research, enabling more precise control over neuronal activity.

SE-04-03

# Nano-fluids at deep-sea hydrothermal vents

**Ryuhei Nakamura**

*RIKEN*

## Abstract

The conversion of ionic gradients into electrical energy is the basis of bioenergetics in modern cells. Similar processes have recently been envisioned for synthetic nanomaterials to harvest energy from salinity gradients, known as blue energy harvesting. These processes require intricate design of nano-fluidic devices, including confined and aligned nanochannel for selective ion transport. Here, we show the spontaneous formation of selective ion transport channels in a natural submarine alkaline hydrothermal vent (HV), allowing it to convert ionic gradients into electrical energy. This finding was based on the first detailed structural and functional analysis of natural alkaline HV materials. Spontaneous formation of ion channels discovered in this study has direct implications towards the origin of life on Earth and beyond. In particular, our study shows how osmotic energy conversion, a vital function in modern life, can occur abiotically in a geological setting. Additionally, the hierarchical aliments of nanomaterials produced in simple geological flow settings offer a geomimetic approach to create intricate self-assembled structures.

SE-05-01

# Leveraging hyperpolarized spin states to visualize biochemical processes

**Kayvan R. Keshari**

*Memorial Sloan Kettering Cancer Center*

## Abstract

Transformation has been shown to have a dramatic impact on the metabolic state of the cell. Recent reports have demonstrated that specific alterations in oncogenes and signaling pathways results in increases in pathway flux as well as diversion of substrates. Moreover, there is an argument that changes in metabolism can directly affect cell fate and thus promote oncogenesis or neurodegeneration. Interrogation of key metabolic pathways in relevant systems has been hindered though by a lack of technologies capable of monitoring metabolism non-invasively in multicellular systems to humans. Recent work has applied quantum approaches to overcome the sensitivity limitations of nuclear magnetic resonance. Through hyperpolarization of NMR active spins in metabolic substrates, one can transiently overcome the limited sensitivity of NMR and MRI for detecting biochemical processes, revealing real time biochemical transformations. This talk will focus on the use of this approach, in conjunction with isotope tracing, to mechanistically interrogate biochemical flux through multiple pathways in living systems.

SE-05-02

# Development of oligopeptide DNP MRI molecular probes for in vivo studies

**Yohei Kondo**

*Institute of Science Tokyo*

## Abstract

Peptides, composed of amino acids, are biomolecules involved in various biological processes through sequence-specific metabolisms and interactions with proteins. In addition, peptides are recognized as a class of pharmaceutical reagents. Therefore, there is a growing interest in detecting and tracking *in vivo* dynamics of peptides, including the metabolism and localization. Hyperpolarization, one of the quantum sensing technologies, can markedly enhance the detection sensitivity of nuclear magnetic resonance (NMR) and magnetic resonance imaging (MRI) and enables *in vivo* real-time analysis using NMR/MRI. Hyperpolarized $^{13}$C-enriched molecules, such as [1-$^{13}$C]pyruvate, have been utilized as reagents for hyperpolarized *in vivo* bioimaging, and human clinical trials for early diagnosis of diseases have been conducted. However, the highly sensitive NMR signal, which is created by hyperpolarization technology, decays back to that in a thermal equilibrium state according to the spin-lattice relaxation time ($T_1$). Due to the limitation of molecular structures that affect $T_1$, hyperpolarized molecular probes derived from amino acids and peptides are only amino acid monomers and dipeptides.

In this presentation, we report the development of hyperpolarized oligopeptide molecular probes on the basis of nuclear spin science and appropriate molecular design[1]. Structure-based $T_1$ relaxation analysis suggests that the C-terminal [1-$^{13}$C]Gly-$d_2$ residue affords sufficient $T_1$ for *in vivo* studies, even in oligopeptides. The developed oligopeptide molecular probes, $^{13}$C-β-casomorphin-5 and $^{13}$C-glutathione, were successfully utilized

to monitor the dynamic *in vivo* metabolisms of the oligopeptides.

1. Yohei Kondo, Yutaro Saito, Tomohiro Seki, Yoichi Takakusagi, Jumpei Morimoto, Hiroshi Nonaka, Koichiro Miyanishi, Wataru Mizukami, Makoto Negoro, Abdelazim Elsayed Elhelaly, Fuminori Hyodo, Masayuki Matsuo, Natarajan Raju, Rolf E. Swenson, Murali C. Krishna, Kazutoshi Yamamoto, Shinsuke Sando, *Sci. Adv., in press*.

SE-05-03

# Next-generation cancer therapy pioneered by the fusion of quantum bioscience and robotic surgery

**Nobu OSHIMA**

*Kyoto Univ./ KCGH*

## Abstract

In next-generation medicine, technologies that visualize the biological properties of specific cells hold vast potential for various applications. For instance, hyperpolarized MRI has already been introduced into cancer clinical practice worldwide. This advanced imaging technology enables real-time observation of specific biological activities within cancerous tissues. From a physician's perspective, hyperpolarized MRI is not only capable of precisely identifying tumor boundaries but also holds the potential to realize "theranostics"—combining diagnosis and treatment in a single approach. In the treatment of solid tumors, surgery remains the most powerful therapeutic method, but with the advent of robotic surgery, we are entering a new era of surgical treatment. Robotic surgery is highly compatible with a range of digital technologies and has the potential to leverage cutting-edge imaging technologies and AI to deliver innovative, unprecedented surgical treatments. These next-generation surgical techniques aim to comprehensively incorporate these technologies to further improve safety and treatment outcomes. In this presentation, I will demonstrate the practical applications of robotic surgery using the latest technologies. Additionally, I will explore the potential for future cancer treatment pioneered by the fusion of quantum life science technologies and robotic surgery, from the perspective of a physician.

SE-06-01

# Advances in quantum sensing for gravity cartography (TBC)

**Michael Holynski**

*U Birmingham*

## Abstract

SE-06-02

# Quantum sensing with atoms and ions

**Paul Hamilton**

*UCLA*

## Abstract

I will discuss two experiments at UCLA towards sensing motion with laser-cooled atoms. The first borrows techniques from cavity quantum electrodynamics (QED) to use an optical cavity to directly read out the motion of an ensemble of neutral atoms over sub-wavelength scales on a microsecond timescale. The second experiment combines techniques from matter wave interferometry and quantum computation towards the development of a single ion gyroscope.

SE-06-03

# Advances in optical frequency comb technology and its impact on atomic and molecular sensing

**Hajime Inaba**

*National Institute of Advanced Industrial Science and Technology*

## Abstract

Optical frequency comb is a light whose comb-shaped spectrum consists of laser modes at equal frequency intervals and is sometimes called an "optical ruler" due to its frequency precision. When they first appeared at the end of the 20th century, their main application was absolute frequency measurement for lasers, but 25 years later their applications have greatly expanded. It is also closely related to atoms and molecules. Here I will introduce the frequency comb and talk about our comb research related to atoms and molecules.

The first topic concerns the application to optical clocks, such as optical lattice clocks. Optical clocks require many frequency-stabilized lasers to cool the atoms. They also use the forbidden transitions of the atoms as clock transitions, and use highly stable lasers to observe their narrow spectral widths. These are very compatible with optical combs.

The second topic concerns an application called "dual-comb spectroscopy", which is mainly used for molecular gas analysis. Dual-comb spectroscopy uses two frequency combs and has the advantages of high resolution, wide bandwidth, and high speed, and it has been enthusiastically studied in recent years with the aim of practical application.

The third topic concerns the frequency comb for wavelength calibration of astronomical spectrograph, known as "astro-comb". To measure the wavelengths of absorption and bright lines of atoms and molecules with high precision using a spectrograph, the spectrograph is used while being calibrated in real time with a frequency comb. Since the resolution of a spectrograph is typically 10 GHz or higher, an optical comb with a repetition frequency sufficiently higher than 10 GHz is required.

SE-07-01

# Imaging metabolism and physiology in cancer

**Murali Cherukuri**

*Personal*

## Abstract

The metabolic adaptability of cancer cells on multiple energy pathways is thought to underlie tumorigenesis in vivo. Metabolism of the cancer cell is diverse with reliance on both aerobic glycolysis and oxidative phosphorylation to meet demands for building blocks and energy equivalents. Metabolic plasticity is also associated with developing resistance to treatment and distal metastases. While there is strong support for shift in cancer cell metabolism to aerobic glycolyses recent studies showed evidence for robust utilization of glucose through the TCA (tricarboxylic acid) cycle. Drugs targeting both these energy pathways have been developed and pre-clinical studies in mice showed promising results alone or in combination. Clinical studies were limited because of off-target toxicities.

Solid tumors have a microenvironment distinctly different from normal tissues. Many factors contribute to the distinct tumor microenvironment including altered metabolism, chaotic blood vessel network, conditions which cause acidotic and hypoxic conditions. The acidotic conditions can further be exacerbated by OxPhos inhibitors which force metabolism to aerobic glycolysis producing additional lactate. Tumor hypoxia can result from inadequate supply of oxygen through defective blood vessel network or from demand outstripping supply or both.

SE-07-02

# In vitro evaluation of cell metabolism by hyperpolarized $^{13}$C-NMR and future biological applications

**Natsuko Miura**

*Osaka Metropolitan University*

## Abstract

Metabolism plays a critical role in cell survival and function, especially under challenging conditions such as hypoxia. To gain deeper insights into the metabolic dynamics of cells in hypoxic environments, we used hyperpolarized $^{13}$C-NMR, a state-of-the-art technique that allows real-time, non-invasive observation of metabolic pathways. In this study, cancer cells and *Saccharomyces cerevisiae* were used as model systems to investigate changes in glycolytic flux and other metabolic pathways under hypoxia. Hyperpolarized $^{13}$C-NMR offers a unique advantage by significantly enhancing signal detection of metabolites, allowing us to monitor key intermediates in real time.

The goal of our research is to control and manipulate cellular metabolism under hypoxic conditions by developing novel molecular tools. These tools aim to modulate specific metabolic pathways and offer potential therapeutic insights for cancer treatment, where hypoxia-induced metabolic shifts are well documented. In addition, we are studying how yeast, a model organism with a well-defined metabolic network, responds to oxygen deprivation, providing comparative insights that may have broader biological applications.

Our results highlight the versatility of hyperpolarized $^{13}$C-NMR in metabolic studies and open new possibilities for real-time observation and manipulation of cellular functions in various biological systems. The future implications of this research extend to both medical and industrial fields, providing a pathway towards targeted metabolic control in disease treatment and biotechnological applications.

SE-07-03

# Development of DNP-MRI visualizing alterations of kidney cancer-associated genes

**Hisashi Hasumi**

*Yokohama City University*

## Abstract

Kidney cancer is a complex disease, originated from a variety of nephron cells under alterations of various kidney cancer-associated genes, most of which are associated with metabolic pathways, and an incomplete development of imaging modalities frequently leads to under- or over-treatment for each patient in both surgical and drug therapies. Here, we present our recent strategy for the development of metabolic imaging modalities, which may classify kidney cancers based on metabolic alterations. DNP-MRI using C13-labelled metabolites successfully displayed metabolic alterations in our PDX library established from various kidney cancer specimens. Of note, the renal tumor with deficiency of fumarate hydratase *(FH)*, an enzymatic gene in TCA cycle, displayed an increased flux from C13-labelled pyruvate into C13-labelled lactate, whereas the renal tumor with deficiency of folliculin *(FLCN)*, a critical regulator for mitochondrial biogenesis, displayed a decreased flux. Our aim is to integrate those imaging data with multi-omics data from WGS, WES, RNA-seq, single cell RNA-seq and spatial RNA-seq analyses and develop imaging modalities, which may non-invasively identify altered kidney cancer-associated genes in each tumor as well as delineate intra-tumor heterogeneity developed in each patient.

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CC-01-01

# Transitioning to quantum secure networks

**Shinya Murai**

*Toshiba Digital Solutions Corporation*

## Abstract

Quantum key distribution (QKD), as an essential part of quantum secure networks, has now been widely introduced not only for research purposes but also for practical use cases. This talk will present several trial cases which indicate how QKD transitions current networks, such as dedicated networks, closed networks, and internet VPNs, into quantum secure networks. In addition, the talk will touch on QKD and post quantum cryptography (PQC) hybrid architecture for protecting whole network systems, and our view on transitioning from QKD networks to quantum internet in the future.

CC-01-02

# Integrating quantum key distribution with optical communication networks

**Takuya Hirano**

*Gakushuin University*

## Abstract

Quantum key distribution (QKD) enables two parties to share a secret key whose secrecy is guaranteed by the laws of quantum physics. QKD is the most advanced quantum technology, having a well-developed theoretical framework and experimental implementations for various industrial applications. Constructing a QKD network by connecting node pairs with QKD significantly enhances the capability of QKD: Communication paths can be made redundant and a secret key can be shared between any two parties that is completely unknows to a third party. Realization of the QKD network is a difficult task requiring a lot of effort, for example, to establish a management mechanism for securely distributing keys between nodes and supplying keys to users. The QKD network shall be a part of communication system consisting of high-speed optical network and routing mechanism.

In this talk, we discuss a possibility of integrating QKD with optical communication networks. In particular, we will review the present status of continuous-variable quantum key distribution, including optical configuration and security analysis, and would like to discuss future prospects for integration with coherent optical communications.

**Acknowledgement**

This work was supported by R&D project of Ministry of Internal Affairs, Grant Number JPMI00316.

CC-01-03

# A quantum-safe network testbed for versatile use cases and applications: National Quantum-Safe Network, Singapore

**Hao Qin**

*National University of Singapore*

## Abstract

In this talk, I will introduce the initiative, and efforts have been recently made in the National Quantum-Safe Network (NQSN) in Singapore. NQSN is a nationwide collaborative platform, and a field-deployed testbed aimed at demonstrating and verifying quantum-safe solutions towards industry applications & use cases. NQSN links up academic, public and private members, targets industry-oriented trials for quantum key distribution (QKD) network with different QKD protocols, post-quantum cryptography (PQC) and classical symmetric key technologies. The NQSN testbed has a star-type QKD network topology, deployed over the existing production-grade fiber infrastructure, featuring multi-QKD protocols and versatile applications & use cases in different Open Systems Interconnection (OSI) layers from various industry players.

CC-02-01

# Constellations for space quantum communications

**Dr Daniel K L Oi**

*SUPA Department of Physics, University of Strathclyde, Glasgow, United Kingdom*

## Abstract

Long-distance quantum communication links enable or enhance a variety of applications in secure communications, distributed sensing timing & navigation, and networked quantum information processing. Distributing entanglement on a global scale will form the basis of the quantum internet, however, the exponential losses in optical fibre and the need for closely spaced quantum repeaters severely limits the prospects of a purely terrestrial-based quantum network. Space-based quantum links have been proposed to overcome the range limitation of fibre with recent satellite demonstrations proving the feasibility of the concept. Quantum satellite constellations will be required to provide wide-scale availability and capacity. Here, I shall cover the challenges and approaches to the use of satellite networks for Earth-spanning quantum-secure communication and entanglement distribution, including the use of space quantum memories and repeaters.

CC-02-02

# Satellite-based QKD R&D and commercialization trends

**Saori Kijima Yokote**

*SKY Perfect JSAT Corporation*

## Abstract

In recent years, the development of quantum key distribution (QKD) and cryptographic techniques have been promoted worldwide. Also in Japan, various QKD research and development projects are being conducted, including a publicly solicited R&D project by Japanese government.
SKY Perfect JSAT Corporation (SJC), Asia's largest satellite operator, participated in 2 Ministry of Internal Affairs and Communications(MIC) R&D projects with National Institute of Information and Communications Technology(NICT) and private companies from2018 to the end of March 2024.
This presentation describes latest satellite-based QKD R&D and commercialization trends in several countries around the world.
The concepts, requirements, and demonstration results of the MIC R&D projects will also be presented.
In addition, SJC's future business development prospects for satellite-based QKD will also be introduced.

CC-02-03

# Secure key generation via optical communication between ISS and a vehicle. ---Toward satellite QKD ---

**Shunsuke Ozawa**

*NICT*

## Abstract

Thanks to the tremendous efforts of many researchers, quantum computers are just one step away from practical use. However, this means that existing encryption methods based on computational security will become vulnerable, and it is recognized as a threat to the security of the current Internet. One solution to this problem is quantum cryptography, and secure key distribution using this method, known as Quantum Key Distribution (QKD), is attracting attention as a way to ensure the security of data communication in the quantum computer era.
This information-theoretically secure method of key data sharing is currently undergoing tests for social implementation in fiber networks, and while it is becoming clear that it is very useful, it has the problem of being difficult to transmit over long distances. As one way to solve this problem, the demonstration of quantum key distribution starting from a satellite is being considered.
In order to develop QKD equipment for satellites and acquire basic technology for space-to-ground single photon communications, we installed an encryption transmitter "SeCRETS" using a physical layer method on the International Space Station in August 2023 and attempted key distribution to a portable optical ground station based on the vehicle, which was successful in March 2024. In this presentation, we will introduce this attempt between the ISS and the ground, as well as the experimental plan for a QKD satellite, which is being promoted as the next plan based on the mission equipment development cultivated in the "SeCRETS" development.

CC-03-01

# Recent progress towards enabling the scalability of quantum hardware using quantum communications

**Hanhee Paik**

*IBM*

## Abstract

I would like to give an update on IBM's recent progress towards scaling quantum computing systems using quantum communication links. Modular quantum computing architecture through scalable high-quality fast quantum communications links is becoming essential to any quantum computing platforms. I will review the IBM Quantum Development roadmap to show IBM's vision of scaling quantum computing systems and introduce the latest achievements to realize this vision using a chip-to-chip and inter-packaging quantum communications. I will close by reviewing the latest advancement in discovering a new LDPC code that can be realizable by on-chip quantum communications links.

CC-03-02

# Entanglement-efficient bipartite-distributed quantum computing

**Mio Murao**

*The University of Tokyo*

## Abstract

We investigate distributed quantum computation (DQC) between two quantum computers connected via a quantum communication channel. By analyzing the distributed implementation of a global quantum circuit through entanglement-assisted local operations and communication, we develop an algorithm to reduce the quantum communication cost given by the entanglement cost in DQC. Our work extends the protocol introduced in [Eisert et al., Phys. Rev. A 62, 052317 (2000)], which implements each nonlocal controlled-unitary gate locally with a single maximally entangled pair, into a packing protocol capable of consolidating multiple nonlocal controlled-unitary gates locally using just one maximally entangled pair. We propose heuristic algorithms for finding an entanglement-efficient packing of distributed operations for a given quantum circuit to be executed by two quantum computers. When applied to the bipartite DQC of unitary coupled-cluster circuits, these algorithms yield a significant reduction in entanglement costs. This method establishes a constructive upper bound on the entanglement cost for DQC of quantum circuits and can be extended to DQC across multiple quantum computers.

Reference: J-Y Wu, K. Matsui, T. Forrer, A. Soeda, P. Andrés-Martínez, D. Mills, L. Henaut and M. Murao, Entanglement-efficient bipartite-distributed quantum computing with entanglement-assisted packing processes, Quantum 7, 1196 (2023)

CC-03-03

# Development of a spin ensemble-based quantum transducer

**Yuimaru Kubo**

*Okinawa Institute for Science and Technology Graduate University*

## Abstract

We are developing a quantum transducer based on an ensemble of nitrogen-vacancy (NV) centers in diamond. To this end, we have designed a hybrid resonator that integrates both microwave and optical cavities. The microwave resonator, using a dielectric material, has demonstrated a high internal quality factor (~$10^4$), while maintaining large apertures for free-space optical access. Strong coupling between the resonator and a diamond sample with nitrogen impurities (P1 centers) has been achieved at 10 mK. In parallel, a Fabry–Pérot optical cavity has been successfully stabilized inside a dilution refrigerator at about 13 millikelvin. The cavity length fluctuations have been measured to be about 18 pm (root mean square) without diamond, whereas it becomes larger when a diamond crystal is inserted into the cavity.

CC-05-01

# Single-photon emitter using a rare-earth atom confined in optical fiber

**Kaoru Sanaka**

*Tokyo University of Science*

## Abstract

Rare-earth atoms in solid-state materials are attractive components for photonic quantum information systems because of their coherence properties even in high-temperature environments. We experimentally perform the single-site optical spectroscopy and optical addressing of a single rare-earth atom in an amorphous silica optical fiber at room temperature with two kinds of rare-earth atoms. The autocorrelation function of photons emitted from a single rare-earth atom shows a direct evidence of the generation of really single photons. The time width of the autocorrelation function is phenomenologically explained by the model of a three-level system, and is determined in practice by the pump rate of the single rare-earth atom. The ability to address single rare-earth atoms provides a very stable and cost-effective technical platform for the realization of a solid-state system especially for single-photon emitters with a large number of spectral channels from visible to mid-infrared wavelengths.

CC-05-02

# Development of frequency-multiplexed quantum repeater system

**Tomoyuki Horikiri**

*YNU*


## Abstract

Quantum communication over long distances faces significant challenges, particularly photon loss in optical fibers. A promising solution to this issue is the quantum repeater, which enables entanglement swapping and distribution across distant nodes. By employing a frequency-multiplexed approach, it is expected to be possible to increase the throughput of quantum communication systems significantly, thereby overcoming many of the distance-related limitations. This study focuses on developing a frequency-multiplexed quantum repeater system based on Pr:YSO quantum memories (QMs). We aim to integrate Pr:YSO QMs with a frequency-multiplexed quantum repeater architecture to enhance quantum communication performance. The system relies on the generation of two-photon pairs through cavity-enhanced two-photon processes, carefully matched to the transition frequencies of Pr:YSO. And a key feature of the proposed system is the use of optical frequency combs for phase-locking and frequency stabilization across multiple elements.

In the talk, we will discuss the current status of the development of our quantum repeater and also introduce studies in real-world fiber optic networks in collaboration with industrial partners. By advancing these technologies, we aim to contribute to the realization of scalable, long-distance quantum networks.

CC-05-03

# Graph state generation for quantum networks

**Sophia Economou**

*Virginia Tech*

## Abstract

The building blocks of quantum networks are quantum repeaters, where photonic quantum information carriers are generated and error corrected through interactions with matter qubits. I will describe two paradigms of quantum repeaters and discuss in each case how careful control of a register of spin qubits can increase the entanglement distribution rate over the network. Specifically, I will describe our recent work on the accurate and fast control of nuclear spin memory qubits coupled to spin defects. I will also discuss the deterministic generation of photonic 'graph' states from such quantum emitters.

CC-06-01

# Post-quantum cryptography (PQC) today, tomorrow, and challenges

**Atsushi Yamada**

*ISARA Corporation*

## Abstract

In August 2024, the (US) National Institute of Standards and Technology (NIST) standardized several post-quantum cryptography (PQC) algorithms. Although these specifications are greatly important, PQC standardization is still far from over. NIST is now developing a standard for the post-quantum signature algorithm FN-DSA (based on the FALCON algorithm), and has also began an "onramp" process to identify and standardize additional signature algorithms. And these are just the basic building blocks. The systems and protocols which will eventually utilize these algorithms need standards as well. For example, the standards for protocols such as TLS, SSH and IKEv2 will need to be updated before they can consume the PQC algorithms.

This talk will cover the status of post-quantum standards and their implementations. We will also review guidelines to migrate cybersecurity infrastructures to PQC. We will discuss the path to PQC, some potential challenges along the way, and of how cryptography inventories are critical to successful migrations. Finally, we will highlight additional benefits of assessing your cryptography posture and conclude that cryptography posture management should be a cybersecurity best practice today.

CC-06-02

# The next-generation quantum technology ecosystem

**Jesse Robbers**

*Quantum Delta NA*

## Abstract

Quantum networks are being roll-out across the globe. Learn what is happening in NL and Europe, what parties are involved and how to set-up an entire quantum ecosystem, starting at the supply chain, service towards end-users and how to prepare for the future Quantum Internet.

CC-06-03

# A case: cybersecurity of financial institutions in quantum computer Era

**Yuto Takahashi**

*The Japan Research Institute, Limited*

## Abstract

The rapid growth of quantum computer technology has led to research into its applications across various fields. In the financial sector, it has already been proposed for option trading and arbitrage, and its future applications are highly expected.
However, the immense computational power of quantum computers poses a significant threat to traditional encryption algorithms. For instance, the authentication and encryption mechanisms used in Internet banking and cash cards could become vulnerable. To ensure the provision of safe and stable financial services in this new era, we need encryption methods that can withstand quantum computing.
Although we eagerly anticipate the advancements in quantum computing, we must also prepare countermeasures. Currently, Post-Quantum Cryptography and Quantum Key Distribution are emerging as potential solutions. Quantum Key Distribution is promising due to its theoretical security, but it faces the challenge of requiring specialized equipment.
To implement more flexible countermeasures, it is important to consider Post-Quantum Cryptography that can be implemented as software. Global academic research on Post-Quantum Cryptography is advancing, and the National Institute of Standards and Technology is leading a project to standardize these algorithms.
We have been closely monitoring global trends, evaluating to these algorithms, and deepening our understanding of Post-Quantum Cryptography. We would like to share an example of our efforts to ensure secure communication in the era of quantum computing from a banking corporation's perspective.

CC-07-01

**Thomas van Himbeeck**

*Telecom Paris*

## Abstract

CC-07-02

# Computationally hard problems for post-quantum cryptography

**Yusuke Aikawa**

*The University of Tokyo*

## Abstract

The security of currently used public key cryptography is based on the computational hardness of problems such as the factorization problem and the discrete logarithm problem of groups. However, as is well known, these problems can be efficiently solved using Shor's algorithm, which has led to ongoing research and standardization efforts for cryptography that is resistant to cryptanalysis using both classical and quantum computers. Such cryptographic schemes are collectively referred to as post-quantum cryptography (PQC for short).

In this talk, we would like to share an overview of the types of PQC and the current trends in standardization. Additionally, we will discuss some of mathematical hardness assumptions underlying PQC, along with an evaluation of their hardness, incorporating our recent results.

CC-07-03

# Recent progress on QAM/QNSC optical transmission

**Masataka Nakazawa**

*Tohoku University*

## Abstract

Recent progress on encrypted optical fiber transmission by employing so-called quantum noise stream cypher with quadrature amplitude modulation (QAM/QNSC) will be presented. QNSC, which is a classical physical layer encryption technique that uses signal masking with quantum noise, has been attracted a lot of attention as a secure long-distance and large-capacity optical transmission scheme. In this presentation, the principle of the QAM/QNSC is first presented, in which I emphasize the importance of the basis bits attached to the original data as an encrypted key comprising of multiple different randomizations. Then, QAM/QNSC with the use of QKD is presented, where the QKD is adopted instead of classical key generation. Since the present technique has an advantage of high-capacity transmission, we show 10 Tbit/s (Pol. Mux,165 ch. WDM with 5G baud/128 QAM) QNSC Transmission over 160 km. Then, I present 40 Gbit/s three dimensional (3D) QNSC real time transmission over 560 km by incorporating not only I and Q channel encryptions but also randomization (masking) in the time domain, which makes it further difficult to decrypt the QNSC signal. Finally, I conclude my talk.

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MA-04-01

# Quantum point defects in wide band gap semiconductors: Donor properties in ZnO and charge states of diamond

**Kai-Mei C. Fu**

*University of Washington*

## Abstract

Quantum point defects which exhibit both spin and optically active states are attractive qubit candidates for quantum sensing and network technologies. Here we present progress on two defect systems: shallow donors in ZnO and deep vacancy-related defects in diamond.
In direct band gap semiconductors, the bound-electron spin states of shallow donors forming the qubit states can be optically accessed via the donor-bound exciton with high radiative efficiency. We have recently measured the optical and coherence properties of In defects in ZnO, *in situ* doped and formed by implantation and annealing. We observe an inhomogeneous linewidth of several GHz, longitudinal spin lifetimes up to 0.5 s and coherence times up to 50 μs which are limited by substrate purity. Two-laser spectroscopy also reveals the large, 100 MHz hyperfine coupling of the In electron spin-1/2 to the In nuclear spin- 9/2. Further, we have demonstrated isolation of single In donors by probing only a small sample volume. Finally, we discuss the outlook for new defect centers in an ultra-pure ZnO host.
A fundamental property that must be controlled in any defect-based technology is the charge state. We demonstrate the use of deep-ultraviolet (DUV) radiation to dynamically neutralize nitrogen- (NV) and silicon-vacancy (SiV) centers in diamond. We first examine the conversion between the neutral and negatively charged NV states by correlating the variation of their respective spectra, indicating that more than 99% of the population of NV centers can be initialized into the neutral charge state. We demonstrate that the bleaching of SiV– induced by the DUV is accompanied by a dramatic

increase in the neutral $SiV^0$ population. Our results on two separate color centers at technologically relevant temperatures indicate a potential for above-band-gap excitation as a universal means of generating the neutral charge states of quantum point defects on demand.

MA-04-02

# Exploring quantum devices with new materials

**Tomohiro Otsuka**

*Tohoku University*

## Abstract

In quantum technologies such as quantum computing, the role of host materials is important. New materials expand the possibilities for new functional quantum devices and technologies. In this presentation, we introduce our research on the exploration of new semiconductor materials and the quantum devices that utilize them, aimed at future semiconductor quantum technologies. We will explain the fabrication and characterization of quantum devices that employ these new materials. We will also introduce related technologies, such as the measurement and control of quantum states. These efforts will contribute to new functional quantum devices and future applications in fields such as quantum communication, sensing, and computing.

MA-04-03

# Quantum computation using electron wave packets

**Michihisa Yamamoto**

*RIKEN*

## Abstract

Standard approaches to quantum computing require significant overhead to correct for errors. The hardware size for conventional quantum processors in solids increases linearly with the number of physical qubits, such as for transmon qubits in superconducting circuits, or electron spin qubits in quantum dot arrays. We propose an alternative approach that utilizes flying electronic wave packets propagating in solid-state quantum semiconductor circuits. Using a novel architecture for the electronic wave packets, hardware requirements are drastically reduced because qubits can be created on-demand and manipulated with a common hardware element, unlike the localized approach of wiring each qubit individually. We also present our recent experiment in this direction, where we realize electronic interference at the level of a single quantized mode that can be used for manipulation of electronic wave packets.