ABOUT QPQIS-2025

Welcome to QPQIS-2025, the 7th International Symposium on Quantum Physics and Quantum Information Science, hosted by Beijing Academy of Quantum Information Sciences (BAQIS). QPQIS-2025 will be held on October 14-16, 2025 (Beijing Time).

QPQIS is a high-profile international academic forum held annually to promote global collaboration and advance the frontiers of quantum science. The symposium features not only established leaders, but also emerging young scholars, providing opportunities for comprehensive and multi-perspective communication through keynote speeches, oral presentations, and interactive poster sessions.

BEIJING ACADEMY OF QUANTUM INFORMATION SCIENCES

Beijing Academy of Quantum Information Sciences (BAQIS) was established on December 24, 2017. It is an innovative research institution initiated by Beijing Municipal Government and co-founded with China's top universities and research institutions such as Tsinghua University, Peking University, Chinese Academy of Sciences, etc.

BAQIS endeavors to address major fundamental issues of quantum physics and quantum information science to push forward next-generation quantum science and technology advancement. BAQIS encompasses five major research fields: quantum state of matter, quantum computation, quantum communication, quantum materials and devices and quantum precision measurement. In the meantime, it has developed two state-of-the-art experimental platforms to support the researches, i.e. the micro-nano processing platform and the synergetic testing platform.

To build a world-class research institution, BAQIS adopts an operating mechanism in line with international standards, coordinates all partners with their distinct and favorable resources, and vigorously introduces the world's top talent. BAQIS also strives to promote international academic exchanges and collaborations through various activities, such as QPQIS (International Symposium on Quantum Physics and Quantum Information Science) and the "Distinguished International Visiting Scholar Program".

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PROGRAM

Day 1 / October 14

OPENING CEREMONY (Moderator: *Tao Xiang* | President of BAQIS)

09:00-09:10 • **Opening Speech**
Qi-Kun Xue | President of BAQIS

SESSION 1 (Session Chair: *Fei Yan* | BAQIS)

09:10-09:45 • **Invited Talk I-01: The Development of Solid State Quantum Computers**
David DiVincenzo | Forschungszentrum Jülich, Germany

09:45-10:20 • **Invited Talk I-02: High-Fidelity Control and Readout of Superconducting Quantum Circuits**
Yasunobu Nakamura | RIKEN / University of Tokyo, Japan

10:20-11:00 • **Group Photo & Tea Break**

SESSION 2 (Session Chair: *Hongqi Xu* | BAQIS)

11:00-11:35 • **Invited Talk I-03: High-Fidelity Multi-Qubit Devices in Silicon**
Seigo Tarucha | RIKEN, Japan

11:35-11:47 • **Oral Talk O-01: Dissipative Probe of Quantum Criticality in 1D Quantum Gases**
Wenlan Chen | Tsinghua University / BAQIS, China

11:47-11:59 • **Oral Talk O-02: Cavity Dark State Strongly Interacting with an Atom Array**
Hao Zhang | Graduate School of China Academy of Engineering Physics, China

11:59-12:11 • **Oral Talk O-03: Electron on Solid Neon Qubits**
Xinhao Li | Westlake University, China

12:11-14:00 • **Lunch / Poster Session**

SESSION 3 (Session Chair: *Heng Fan* | IOPCAS / BAQIS)

14:00-14:35 • **Invited Talk I-04: Driven Atomic Josephson Junctions**
Luigi Amico | The Technology Innovation Institute , The United Arab Emirates

14:35-14:47 • **Oral Talk O-04: *f*-Sum Rules for Dissipative Systems**
Wei Zhang | Renmin University of China / BAQIS, China

14:47-14:59 • **Oral Talk O-05: Quantum and Nonlinear Cavity Magnomechanics**
Jie Li | Zhejiang University, China

14:59-15:11 • **Oral Talk O-06: Bath-Engineering Technique for Criticality-Based Quantum Metrology with Amplitude Noise**
Qing Ai | Beijing Normal University, China

15:11-15:35 • **Tea Break**

SESSION 4 (Session Chair: *Kihwan Kim* | Tsinghua University / BAQIS)

15:35-16:10 **Invited Talk I-05: Quantum-Inspired Classical Optical Metrology**
Yoon-Ho Kim | Pohang University of Science & Technology, Korea

16:10-16:45 **Invited Talk I-06: Measurement Induced Transitions in Light-Matter Systems**
Rosario Fazio | Abdus Salam ICTP, Italy

16:45-16:57 **Oral Talk O-07: Moiré NEMS for Quantum Sensing**
Xin Zhang | Institute of Semiconductors, CAS, China

16:57-17:09 **Oral Talk O-08: Symmetry Enriched Topological Orders and Distinct Monopole Charges for Dipole-Octupole Spin Ices**
Gang Chen | Peking University, China

17:09-17:21 **Oral Talk O-09: Exploring Novel Quantum Computing Architectures in Topological Hybrid Devices**
Panagiotis Kotetes | BAQIS, China

Day 2 / October 15

SESSION 5 (Session Chair: *Yulong Liu* | BAQIS)

09:00-09:35 **Invited Talk I-07: Quantum Backaction, Entanglement and Gravity with Mechanical Oscillators**
Mika Sillanpää | Aalto University, Finland

09:35-10:10 **Invited Talk I-08: Time as a Resource in Quantum Metrology**
Lorenzo Maccone | University of Pavia, Italy

10:10-10:35 **Tea Break**

SESSION 6 (Session Chair: *Shiqian Ding* | Tsinghua University / BAQIS)

10:35-11:10 **Invited Talk I-09: Quantum and Topological Phononics**
Albert Schliesser | University of Copenhagen, Denmark

11:10-11:22 **Oral Talk O-10: Improved Nondemolition Qubit Readout with Squeezed Light**
Wei Qin | Tianjin University, China

11:22-11:34 **Oral Talk O-11: Optomechanical Dark-Mode-Breaking Cooling**
Jiteng Sheng | East China Normal University, China

11:34-11:46 **Oral Talk O-12: Microwave-Optical Entanglement Dynamics in Cavity Electro-Optics**
Liu Qiu | Zhejiang University, China

11:46-14:00 **Lunch / Poster Session**

SESSION 7 (Session Chair: *Yiquan Zou* | BAQIS)

14:00-14:35 **Invited Talk I-10: Quantum Simulation and Optimization with Rydberg Atoms and Molecules**
Peter Schmelcher | University of Hamburg, Germany

14:35-15:10 **Invited Talk I-11: On the Horizon: the ^{229m}Th Nuclear Clock**
Peter Thirolf | Ludwig-Maximilians-Universität München, Germany

15:10-15:22 **Oral Talk O-13: A Continuous-Wave Laser at 148 nm for the Th-229 Nuclear Clock**
Shiqian Ding | Tsinghua University / BAQIS, China

15:22-15:34 **Oral Talk O-14: Engineering 2D Spin Networks by On-Surface Encapsulation of Azafullerenes in Nanotemplates**
Denis Arčon | Jožef Stefan Institute, Slovenia

15:34-15:46 **Oral Talk O-15: Non-Equilibrium Criticality-Enhanced Quantum Sensing**
Abolfazl Bayat | University of Electronic Science and Technology of China, China

15:46-16:00 **Tea Break**

16:00-17:30 **Poster Session**

Day 3 / October 16

SESSION 8 (Session Chair: *Fei Yan* | BAQIS)

09:00-09:35 **Invited Talk I-12: Passive Two-Photon Dissipation for Bit-Flip Error Correction of a Cat Code**
Benjamin Huard | Ecole Normale Supérieure de Lyon, France

09:35-10:10 **Invited Talk I-13: Advancing the Control of Superconducting Qubits for Quantum Information Processing**
Stefan Filipp | Technical University of Munich, Germany

10:10-10:35 **Tea Break**

SESSION 9 (Session Chair: *Haifeng Yu* | BAQIS)

10:35-11:10 **Invited Talk I-14: Efficient Implementation of Arbitrary Two-Qubit Gates using Unified Control**
Fei Yan | BAQIS, China

11:10-11:22 **Oral Talk O-16: Superconducting Electronics for Qubit Control and Microwave Quantum State Preparation**
Zhirong Lin | Shanghai Institute of Microsystem and Information Technology, CAS, China

11:22-11:34 • **Oral Talk O-17: Two-Qubit Gate Error Revisited for Non-Markovian Noise**
Ruixia Wang | BAQIS, China

11:34-11:46 • **Oral Talk O-18: Analytical Control for Quantum Computation and Simulation**
Boxi Li | Forschungszentrum Jülich, Germany

11:46-14:00 • **Lunch / Poster Session**

SESSION 10 (Session Chair: *Dong Liu* | Tsinghua University / BAQIS)

14:00-14:35 • **Invited Talk I-15: Superconducting Kerr Parametric Oscillators based Bosonic Qubit - A Practical Quantum Information Processing Platform**
Jaw-Shen Tsai | Tokyo University of Science, Japan

14:35-15:10 • **Invited Talk I-16: Unlocking Quantum Advantage: Applying Lie Theory to the Challenges of VQAs**
Shengyu Zhang | Tencent, China

15:10-15:22 • **Oral Talk O-19: Efficient Pulse-Level Recompilation of Quantum Circuits: Jenga-Krotov Algorithm and Beyond**
Xin Wang | City University of Hong Kong, China

15:22-15:34 • **Oral Talk O-20: Toward Scalable, High-Fidelity Fluxonium-Based Quantum Devices**
Lijing Jin | Quantum Science Center of Guangdong–Hong Kong–Macao Greater Bay Area, China

15:34-15:46 • **Oral Talk O-21: Sources of Decoherence in Qubits Based on Disorder Superconducting Materials**
Feng Wu | Zhongguancun Laboratory, China

CLOSING CEREMONY

15:46-16:10 • **Closing Remarks & Announcement of Best Poster Awards**

Invited Talks

Day 1 Oct-14 2025
Session 1 Invited talk I-01 09:10 - 09:45

The Development of Solid State Quantum Computers

Learn More

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I will look back at the 30-year history of theory and experiment on solid-state approaches to quantum computers. Clear ideas emerged very soon for functioning one- and two-qubit systems, which represented frontier concepts in solid-state quantum devices. But it took much longer to incorporate the architectural, systems, and scalability criteria that have now become essential for progress towards large-scale machines. I will follow the thread of both semiconductor (spin) qubit systems, as well as today's leading superconducting (transmon) platforms. The pursuit of the goal has been a marathon, but the finish line (or perhaps first way-station) seems now to be in sight.

Day 1 Oct-14 2025
Session 1 Invited talk I-02 09:45 - 10:20

High-Fidelity Control and Readout of Superconducting Quantum Circuits

Learn More

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[2] Department of Applied Physics, Graduate School of Engineering, The University of Tokyo, Japan

Quantum computing requires high-precision control and measurement of large-scale quantum systems with many degrees of freedom. We are developing technologies for superconducting quantum computing platforms aiming at scalable, fast, and high-fidelity operations. Our efforts include 2D integration of transmon qubits, fast (<100 ns), high-fidelity (>99.9%) frequency-multiplexed qubit readout [1], fast (<50 ns), high-fidelity (>99.9%) two-qubit gates with a tunable double-transmon coupler [2,3], and broadband low-noise Josephson traveling-wave parametric amplifiers [4].

[1] P.A. Spring et al., PRX Quantum **6**, 020345 (2025).
[2] R. Li et al., Phys. Rev. X **14**, 041050 (2024).
[3] R. Li et al., Phys. Rev. Applied. **23**, 064069 (2025).
[4] C.W.S. Chang et al., arXiv:2503.07559.

Day 1 Oct-14 2025
Session 2 Invited talk I-03 11:00 - 11:35

High-Fidelity Multi-Qubit Devices in Silicon

Learn More

Seigo Tarucha
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Silicon quantum dots provide a promising platform for application to spin-based quantum computing with high-fidelity qubits. The high-fidelity operation of qubits is an important perquisite for implementing fault tolerant computation and helpful to reduce the qubit overhead for logical operations. We have recently achieved high enough fidelities exceeding fault-tolerance thresholds in single and two-qubit gates, using isotopically purified 28Si/SiGe.

In this talk I will review recent advances in further improving the gate fidelities and discuss the charge noise to affect the spin dynamics. The qubit performance is usually studied in one or two qubit devices, but it may be more important to operate multiple qubits. We have used a five-qubit device to achieve the highest level of fidelity in all five qubits by carefully calibrating the gate errors and appropriately shape the gate pulses to eliminate the crosstalk between qubits. I will discuss the charge noise in the background as a limiting noise source to the fidelity.

*This work is supported by Moonshot program target 6.

Day 1 Oct-14 2025
Session 3 Invited talk I-04 14:00 - 14:35

Driven atomic Josephson Junctions

Learn More

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Atomic Josephson junctions can be realized by coupling two atomic clouds. I will report on the experimental work to realize and study atom Junctions both in the cases the system is quasi-2d and 3d, and from weak link to tunneling barrier regimes. In particular, I will consider a driven atomtronic circuit in which the position of the junction is periodically modulated. I will discuss the theory and the experiments that has led led to the observation of the Shapiro steps in the system. By periodically modulating also the barrier height, I will demonstrate that the circuit realizes an atomic Josephson amplifier. This works provide a pathway toward tunable atomtronic circuits with potential applications in quantum sensing.

References

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[2] G. Del Pace, D. Hernández-Rajkov, V. P. Singh, N. Grani, M. Frómeta Fernández, G. Nesti, J. A. Seman, M. Inguscio, L. Amico, G. Roati, 'Shapiro steps in strongly-interacting Fermi gases', arXiv:2409.03448
[3] E. Bernhart, M. Röhrle, V. P. Singh, L. Mathey, L. Amico, H. Ott, 'Observation of Shapiro steps in an ultracold atomic Josephson junction', arXiv:2409.03340
[4] VP Singh, L Amico, L Mathey, 'Atomic Josephson Parametric Amplifier', arXiv preprint arXiv:2503.20890
[5] VP Singh, E Bernhart, M Röhrle, H Ott, L Mathey, L Amico, 'Weak-link to tunneling regime in a 3D atomic Josephson junction', arXiv preprint arXiv:2509.03591

Day 1 Oct-14 2025
Session 4 Invited talk I-05 15:35 - 16:10

Quantum-Inspired Classical Optical Metrology

Learn More

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Pohang University of Science and Technology, Korea

Quantum metrology harnesses entanglement to surpass the standard quantum limit and approach the Heisenberg limit—the ultimate bound on measurement precision. A representative example is the use of N-photon entangled states, such as N00N states, which enable phase sensitivity scaling as 1/N, beyond the classical limit of 1/√N. However, entanglement is a fragile resource; decoherence can degrade it into classical correlations, diminishing its advantage for precision measurements. Interestingly, certain classical correlations can reproduce quantum-like interference effects in correlation-based interferometry, enabling robust and experimentally accessible metrology schemes. In this context, I will present second-order correlation interferometry with thermal light, which exhibits 2ϕ phase modulation—analogous to two-photon quantum interference—and an effective second-order coherence time far exceeding that of the thermal light source [Phys. Rev. Lett. 119, 263603 (2017); Opt. Lett. 45, 6748 (2020)]. This classical two-photon coherence enables new sensing modalities, such as coherent LIDAR with incoherent light, offering robustness against turbulence and background noise [Phys. Rev. Lett. 131, 223602 (2023)]. These results point toward extending classical correlation interferometry to multi-photon regimes, offering a practical framework for exploring classical analogues of quantum-enhanced sensing techniques.

INVITED TALKS

Day 1 Oct-14 2025
Session 4 Invited talk I-06 16:10 - 16:45

Measurement Induced Transitions in Light-Matter Systems

Learn More

Rosario Fazio
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Dipartimento di Fisica, Università di Napoli "*Federico II*", Napoli, Italy

Monitored many-body quantum system shows a rich phenomenology that is invisible at the level of its average state, the density matrix. Measurement induced phase transitions were discovered in a variety of systems ranging from quantum circuits in the presence of projective measurements to unravelled dynamics of open systems. A key challenge in observing measurement-induced phase transitions is the mitigation of the post-selection barrier, which causes the reproducibility of specific sequences of measurement read-outs—the trajectory—to be exponentially small in system size. I will discuss the properties of monitored light-matter systems where the post-selection barrier can be mitigated.

1. G. Passarelli, X. Turkeshi, A. Russomanno, P. Lucignano, M. Schirò, and R. Fazio, *Phys. Rev. Lett.* **132**, 163401 (2024).
2. Z. Li, A. Delmonte, X. Turkeshi, and R. Fazio, *Nat. Comm.* **16**, 4329 (2025).
3. A. Delmonte, Z. Li, G. Passarelli, E.Y. Song, D. Barberena, A.M. Rey, and R. Fazio, *Phys. Rev. Research* **7**, 023082 (2025).

Day 2 Oct-15 2025
Session 5 Invited talk I-07 9:00 - 9:35

Quantum Backaction, Entanglement and Gravity with Mechanical Oscillators

Learn More

[1] Mercier de Lépinay, L., [1]Ockeloen-Korppi, C. F.,
[2] Woolley, M. J., [1]Herbst, M., [1]Sillanpää, M. A.
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Quantum mechanics sets a limit for the precision of continuous measurement of the position of an oscillator. Mechanical oscillators affected by radiation pressure forces allow to explore such quantum limits in measurement and amplification. An interesting setup for these purposes consist of superconducting microwave cavities coupled to micromechanical vibrating membranes. We show how it is possible to measure an oscillator without quantum back-action of the measurement by constructing one effective oscillator from two physical oscillators. We realize such a quantum mechanics-free subsystem using two micromechanical oscillators, and show the measurements of two collective quadratures while evading the quantum back-action by 8 decibels on both of them, obtaining a total noise within a factor of 2 of the full quantum limit. By perturbing the measurement slightly, such measurements could be used to generate stabilized entanglement between two macroscopic mechanical oscillators. This prepares a canonical entangled state known as the two-mode squeezed state. We carry out this measurement, and verify the existence of entanglement in the steady state by direct access to fluctuations in all the collective motional quadratures.

These findings enable exciting possibilities for further explorations of the physical reality. If made massive enough, the devices may enable observation of gravity between masses down to the Planck mass which is the fundamental mass scale in general relatively and may correspond to the scale where quantum gravitational effects become relevant. I will describe our experimental efforts towards creating systems that could exhibit nonlocal quantum correlations and gravity at the same time.

Day 2 Oct-15 2025
Session 5 Invited talk I-08 09:35 - 10:10

Time as a Resource in Quantum Metrology

Learn More

Lorenzo Maccone
University of Pavia, Italy

I'll present recent results from my group and others that prove how time dependence can be seen as a resource for quantum metrology. In particular, we show how the Heisenberg scaling implies a quadratic time dependence in the growth of the quantum Fisher information whereas the standard quantum limit can only attain a linear time dependence. Moreover, I will show how these metrological ideas can lead to novel ways to estimate time correlations.

Day 2 Oct-15 2025
Session 6 Invited talk I-09 10:35 - 11:10

Quantum and Topological Phononics

Learn More

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Ultrasound waves in membrane resonators with engineered phononic modes can couple strongly to optical, microwave and spin degrees of freedom. We have used this to demonstrate precision measurement of phononic mode excitations at[1] and beyond[2] the standard quantum limit, and realized entanglement of optical fields mediated by phonons[3]. This level of control enables new applications in quantum sensing and information processing, such as spin microscopy[4] and mechanical quantum memories[5].

In recent years, there has been growing interest in using itinerant phonons to transport, mediate, and process quantum signals by routing them in waveguides[6,7]. In such applications,reducing propagation loss and backscattering is paramount.

To this end, we have developed a new topological phononic waveguide that combines the concept of a valleyHall topological insulator with the soft clamping technique in thin SiN membranes[8]. We demonstrate that its propagation loss due to dissipation is as low as 3 dB/km at megahertz

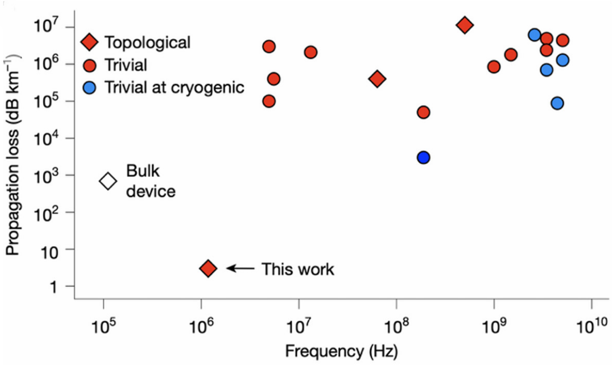

Figure 1. Propagation loss measured for on-chip phonon waveguides due to sound absorption

INVITED TALKS

frequencies, four orders of magnitude lower than existing on-chip phononic systems at room temperature.

We wrap such waveguides up in a triangular path and obtain high (~10^6) finesse on-chip phonon cavities. Using a robust spectroscopic technique, we quantify backscattering of phonons in these structures that include also sharp bends. We find a backscattering probability as low as ~0.01% per bend. Such low-loss, low-backscattering phononic waveguides offer a promising platform for classical and quantum sensors and transducers.

References

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7. T. Shah, C. Brendel, V. Peano and F. Marquardt, Rev. Mod. Phys., 2024, **96**, 021002.
8. X. Xi, I. Chernobrovkin, J. Košata, M. B. Kristensen, E. Langman, A. S. Sørensen, O. Zilberberg and A. Schliesser, Nature, 2025, **642**, 947–953.

Day 2 Oct-15 2025
Session 7 Invited talk I-10 14:00 - 14:35

Quantum Simulation and Optimization with Rydberg Atoms and Molecules

Learn More

Peter Schmelcher
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Rydberg atoms and molecules have become a major platform for quantum simulation and computation in the course of the recent years. This development is based on preparing ultracold ensembles of atoms and individual atom control augmented, more recently, by the possibility to load atoms into optical tweezer arrays followed by their long-range interactions via Rydberg excitations. We provide a review on some of our most recent results on quantum phases of strongly interacting Rydberg systems in low dimensions. We hereby focus on setups that involve two Rydberg states and show both short- and long-range interactions. The competition among the van der Waals and the dipole-dipole interaction is responsible for the formation of extended Luttinger liquid phases and bond-order density waves. For the exotic species of ultralong-range Rydberg molecules we will describe in a nutshell our most recent discoveries on the Impact of non-adiabatic interactions mixing electronic and vibrational dynamics such that vibronic eigenstates and resonances are found on very unusual length and time scales. The final topic of this presentation is dedicated to our focus on quantum optimization.In this context we address graph theoretical (MIS,MAXCUT) optimization problems and in particular, more recently, also integer programming problems including the traveling salesman problem. Our approach is twofold: the Rydberg quantum annealer approach and the digital bottom up quantum computing circuitry design. A circuit-based scalable quantum algorithm is presented using multiple interacting qudits for which we show a quantum speed-up for solving the IP problem.

Day 2 Oct-15 2025
Session 7 Invited talk I-11 14:35 - 15:10

On the Horizon: the ^{229m}Th Nuclear Clock

Learn More

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The quest for an optical nuclear frequency standard, the 'nuclear clock' based on the elusive and uniquely low-energetic 'thorium isomer' ^{229m}Th, has increasingly triggered experimental and theoretical research activities in numerous groups worldwide in the last decade. Today's most precise timekeeping is based on optical atomic clocks. However, those could potentially be outperformed by a nuclear clock, based on a nuclear transition instead of an atomic shell transition. Only one nuclear state is known so far that could drive a nuclear clock: the 'Thorium Isomer ^{229m}Th', i.e. the isomeric first excited state of ^{229}Th, representing the lowest nuclear excitation so far reported. Such a nuclear clock promises intriguing applications in applied as well as fundamental physics, ranging from geodesy and seismology to the investigation of possible time variations of fundamental constants and the search for Dark Matter [1].
After years of nuclear-spectroscopy driven identification and characterization activities of ^{229m}Th, the year 2024 witnessed seminal breakthroughs with first laser-driven excitations of the isomeric nuclear resonance in ^{229}Th, both using intense broad-band [2,3] and VUV frequency-comb based narrow-band lasers [4], respectively. Hardly any physical observable experienced an improvement by 11 orders of magnitude within only 5 years, as it was reached for the excitation energy of the thorium isomer. Hence, the question is no longer 'Will there be a nuclear clock?', but rather 'Which types of nuclear clocks with which properties will be realized in the coming years?', driven by the requirements of a variety of fundamental and applied physics applications. While recent progress with optical excitation of ^{229m}Th was achieved via fluorescence detection in a solid-state approach using doped large-bandgap crystals and thin films [5], recently also laser-driven conversion-electron Mössbauer spectroscopy of the thorium isomer was demonstrated [6], while the complementary approach using individual laser-cooled trapped ions in vacuum is still under study.
The talk will review the status and perspectives of ongoing activities towards realizing a nuclear frequency standard based on the thorium isomer both in the solid-state and trapped ^{229m}Th^{3+} ion approach.

[1] E. Peik et al., Quantum Sci. Technol. **6**, 034002 (2021)
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[3] R. Elwell et al., Phys. Rev. Lett. **133**, 013201 (2024)
[4] Ch. Zhang et al., Nature **633**, 63-70 (2024)
[5] Ch. Zhang et al., Nature **636**, 603 (2024)
[6] R. Elwell et al., arXiv:2506.03018

Day 3 Oct-16 2025
Session 8 Invited talk I-12 9:00 - 9:35

Passive Two-Photon Dissipation for Bit-Flip Error Correction of a Cat Code

Learn More

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Alice and Bob, Paris

Bosonic codes offer a resource-efficient method to quantum error correction [1]. Of particular interest, autonomous correction was successfully demonstrated for cat codes [2–5], where the logical $|0\rangle$ and $|1\rangle$ states are coherent states of opposite amplitudes $|\alpha\rangle$ and $|-\alpha\rangle$ in a superconducting resonator with single-photon loss rates κ1 as low as possible. They correct bit-flip errors by either using the non-linearity of the oscillator or parametrically pumping couplers to produce two-photon dissipation at a rate κ2. The bit-flip time increases exponentially with |α|^2 while the phase-flip rate only increases linearly with |α|^2. In this work, we introduce and experimentally demonstrate a new superconducting circuit designed to correct for bit-flip errors of cat codes. Crucially, the two-photon dissipation does not require any pump, so that a single drive is required to stabilize the qubit manifold. This is obtained by nonlinearly coupling the cat qubit to a buffer mode that resonates at twice the frequency of the cat qubit.
We experimentally demonstrate unprecedented ratios κ2/κ1, so that bit flip times well over a ms can be reached with only a few photons [6]. We also demonstrate quantum gates on this corrected cat qubit [7].
This work was partly supported by the grant ANR-19-QUAN-0006.

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7. A. Marquet et al., Phys. Rev. Applied 22, 034053 (2024).

Day 3 Oct-16 2025
Session 8 Invited talk I-13 9:35 - 10:10

Advancing the Control of Superconducting Qubits for Quantum Information Processing

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Stefan Filipp
Technical University of Munich, Germany

To unlock the full potential of quantum computing, we must manufacture, control and measure scalable quantum systems with unprecedented accuracy and precision. In this presentation, I will focus on superconducting qubits, one of the most promising platforms for quantum computation. I will outline the key building blocks of a quantum processor and then demonstrate how we use optimal control techniques to achieve robust single-qubit operations and high-fidelity two-qubit gates. By leveraging parametric drives, we utilize multi-qubit tunable couplers not only to perform entangling operations between qubits, but also for resetting the qubit, to mitigate leakage into higher excited states, and to enable tunable readout. Furthermore, we harness these parametrically driven couplers to distribute entanglement across the quantum processor, paving the way for efficient quantum state preparation.

Day 3 Oct-16 2025
Session 9 Invited talk I-14 10:35 - 11:10

Efficient Implementation of Arbitrary Two-Qubit Gates using Unified Control

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Fei Yan
Beijing Academy of Quantum Information Sciences, China

The set of quantum logic gates that can be easily implemented is fundamental to the performance of quantum computers, as it governs the accuracy of basic quantum operations and dictates the complexity of implementing quantum algorithms. Traditional approaches to extending gate sets often require operating devices outside the ideal parameter regimes used to realise qubits, leading to increased control complexity while offering only a limited set of gates. Here, we experimentally demonstrate a unified and versatile gate scheme capable of generating arbitrary two-qubit gates using only an exchange interaction and qubit driving on a superconducting quantum processor. We achieve high fidelities averaging 99.38% across a wide range of commonly used two-qubit unitaries, enabling precise multipartite entangled state preparation. Furthermore, we successfully produce a B gate, which efficiently synthesizes the entire family of two-qubit gates. Our results establish that fully exploiting the capabilities of the exchange interaction can yield a comprehensive and highly accurate gate set. With maximum expressivity, optimal gate time, demonstrated high fidelity, and easy adaption to other quantum platforms, our unified control scheme offers the prospect of improved performance in quantum hardware and algorithm development.

Day 3 Oct-16 2025
Session 10 Invited talk I-15 14:00 - 14:35

Superconducting Kerr Parametric Oscillators Based Bosonic Qubit - A Practical Quantum Information Processing Platform

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Jaw-Shen Tsai
Tokyo University of Science & RIKEN, Japan

Recently, there has been a renewed interest in using quantum tunneling in phase space of a Kerr parametric oscillator (KPO) as a resource for quantum information processing. In a planar superconducting KPO we observed quantum interference induced by such tunneling and its dynamics through Wigner tomography. A complete mapping from Fock states to cat states was demonstrated. We perform 1-bit X-gate and Z-gate operations [1] as well as 2-bit iSWAP quantum logic operation [2]. These results indicate that KPOs can be a scalable quantum information processing platform.

1. D. Iyama, et al. "*Observation and manipulation of quantum interference in a superconducting Kerr parametric oscillator*". Nat Commun 15, 86 (2024).
2. Daisuke Hoshi, et al, "*Entangling Schrödinger's cat states by bridging discrete- and continuous-variable encoding*", Nature Communications 16, 1309 (2025)

INVITED TALKS

Day 3 Oct-16 2025
Session 10 Invited talk I-16 14:35 - 15:10

Unlocking Quantum Advantage: Applying Lie Theory to the Challenges of VQAs

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Shengyu Zhang
Tencent, China

Variational quantum algorithms (VQAs) leverage classical optimization to train parameters in parameterized quantum circuits, offering a promising approach for both near-term quantum computing and future quantum AI. However, their deployment is hindered by significant challenges, including barren plateaus, the quality of local minima, efficient gradient estimation, hardware and sampling noises, and quantum circuit design.

In this talk, we will explore how Lie theory has recently emerged as a powerful and unifying framework for rigorously analyzing and addressing these challenges. We will showcase its effectiveness through a series of recent results. First, we present a Lie-algebraic analysis of the Quantum Approximate Optimization Algorithm (QAOA) applied to combinatorial optimization on special graph classes. For cycle graphs, we fully characterize the underlying Lie algebra---deriving its dimension, an explicit basis, its center, and its decompositions into simple subalgebras with explicit bases. This analysis reveals that QAOA on these graphs avoids the barren plateau problem—a common training obstacle in VQAs. Second, we will introduce methods for efficiently constructing large, expressive Lie algebras from smaller, more manageable ones. Third, we will present a quantum recurrent embedding architecture, analyze its trainability, and demonstrate its effectiveness in quantum supervised learning tasks. Collectively, these results establish a foundational framework for algebraic analysis of VQAs and illustrate new strategies for variational quantum algorithm design. We hope that this line of work inspires further systematic research at the intersection of quantum computing and Lie theory.

Oral Talks

Day 1 Oct-14 2025
Session 2 Oral Talk O-01 11:35-11:47

Dissipative Probe of Quantum Criticality in 1D Quantum Gases

Wenlan Chen[1, 2]
[1] Tsinghua University, China
[2] Beijing Academy of Quantum Information Sciences, China

Dissipation is an unavoidable feature of quantum systems, typically associated with decoherence and the modification of quantum correlations. Here we demonstrate that controlled dissipation can serve as a probe for intrinsic correlations in quantum many-body systems. Applying constant dissipation in ultracold atomic systems, we observe universal dissipative dynamics in strongly correlated one-dimensional quantum gases. Specifically, we find a universal stretched-exponential decay of the total particle number, where the stretched exponent measures the anomalous dimension of the spectral function—a critical exponent to characterize strong quantum fluctuations.

In the second part, I will show experimentally that the precise Kibble-Zurek scaling can be retained in the near-critical crossover regime. The Kibble-Zurek scaling reveals the universal dynamics when a system is linearly ramped across a critical point of symmetry-breaking phase transition. In reality, inevitable finite-size effects or symmetry-breaking perturbations can often smear out the critical point and render the phase transition into a smooth crossover. We show that the key ingredient to achieving the precise Kibble-Zurek scaling in the near-critical crossover regime is that the system size and the symmetry-breaking field must be appropriately scaled following the variation of ramping speeds. The experiment is performed in a reconfigurable Rydberg atom array platform, and strengthen the Kibble-Zurek scaling as an increasingly valuable tool for investigating phase transition in quantum simulation platforms.

Reference:
[1] Yajuan Zhao, Ye Tian, Jilai Ye, Yue Wu, Zihan Zhao, Zhihao Chi, Tian Tian, Hepeng Yao, Jiazhong Hu, Yu Chen, Wenlan Chen. “Universal dissipative dynamics in strongly correlated quantum gases”. Nature Physics 21, 530 (2025)
[2] Tao Zhang, Hanteng Wang, Wenjun Zhang, Yuqing Wang, Angrui Du, Ziqi Li, Yujia Wu, Chengshu Li, Jiazhong Hu, Hui Zhai, Wenlan Chen. “Observation of Near-Critical Kibble-Zurek Scaling in Rydberg Atom Arrays”. arXiv:2505.07930

Day 1 Oct-14 2025
Session 2 Oral Talk O-02 11:47-11:59

Cavity Dark State Strongly Interacting with an Atom Array

Hao Zhang[1]
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In the field of quantum information science, optical cavities are widely used to enhance the interaction between photons and atoms. As described in standard textbooks, the electromagnetic field within a resonant cavity forms a standing wave pattern, which has antinodes and nodes. To achieve maximal coupling between atoms and photons, it is conventional to position the atoms at the antinodes, where the field strength is the strongest.

However, in our experiment with an optical ring cavity strongly interacting with an atom array, we have realized a special type of resonant **cavity dark state**. In this state, the light field nodes—where the field strength is zero—are dynamically locked to the positions of the atoms, thereby completely shielding the atoms from the light field [1]. This suppresses unwanted photon scattering due to atomic spontaneous emission, significantly reducing photon loss. At the same time, it enables highly efficient photon conversion through collective interactions mediated by the atomic array [2].

This system introduces a new method for controlling photon-photon interactions by configuring the spatial structure of atomic arrays, opening up new possibilities for all-optical quantum information processing and quantum network applications.

[1] Xiaotian Zhang, Zhanhai Yu, Hongrui Zhang, Di Xiang, and Hao Zhang, Physical Review Research **6**, L042026 (2024).
[2] Xinwei Li, Yijia Zhou, and Hao Zhang, Physical Review Applied **21**, 044028 (2024).

Day 1 Oct-14 2025
Session 2 Oral Talk O-03 11:59-12:11

Electron on Solid Neon Qubits

Xinhao Li[1]
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One of the bottlenecks in developing solid-state quantum bit systems is decoherence caused by environmental noise. At cryogenic temperatures, inert element substrates can provide a near-vacuum, low-noise environment for surface electrons, theoretically significantly suppressing decoherence sources. This study explores a novel quantum bit based on single electrons on the surface of solid neon, verifying its potential in long coherence times, high-fidelity control, and scalability. Using a circuit quantum electrodynamics architecture, we achieved addressing of its charge quantum states [1]. By optimizing materials and quantum control, we confirmed the low-noise characteristics of the solid neon surface, achieving a coherence time on the order of 0.1 ms and single-qubit gates with 99.97% fidelity [2,3]. Additionally, we demonstrated a two-qubit gate based on charge-charge interactions [4]. This research lays the foundation for advancing this emerging quantum system, enabling hybrid multi-system integration and the development of related applications.

[1] Zhou, X., Koolstra, G., Zhang, X., Yang, G., Han, X., Dizdar, B., ... & Jin, D. (2022). Single electrons on solid neon as a solid-state qubit platform. Nature, 605(7908), 46-50.
[2] Zhou, X., Li, X., Chen, Q., Koolstra, G., Yang, G., Dizdar, B., ... & Jin, D. (2024). Electron charge qubit with 0.1 millisecond coherence time. Nature Physics, 20(1), 116-122.
[3] Li, X., Wang, C. S., Dizdar, B., Huang, Y., Wen, Y., Guo, W., ... & Jin, D. (2025). Noise-resilient solid host for electron qubits above 100 mK. arXiv:2502.01005.
[4] Li, X., Huang, Y., Han, X., Zhou, X., & Jin, D. (2025). Coherent manipulation of interacting electron qubits on solid neon. arXiv:2503.23738.

Day 1 Oct-14 2025
Session 3 Oral Talk O-04 14:35-14:47

f-Sum Rules for Dissipative Systems

Xin-Xin Yang[1], Bo-Hao Wu[1], Yu Chen[2], and Wei Zhang[1,3],
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[2]Graduate School of China Academy of Engineering Physics, Beijing, China
[3]Beijing Academy of Quantum Information Sciences, Beijing, China

The *f*-sum rules set general constraints on the response of a quantum many-body system to an external probe and hold significant relevance in the realm of various spectroscopy measurements. In practical conditions, a system unavoidably couples with the environment and acquires effective dissipation. In this talk, we derive and prove a set of *f*-sum rules for dissipative systems. Within the framework of linear response theory, we obtain the system response in both linear order of probe field and dissipation parameter. We formulate and prove one first-order and two second-order dissipative *f*-sum rules. These rules are validated numerically for some example models, and the realization schemes are proposed. In addition, the potential applications are discussed for two interacting many-body systems.

[1] X. Yang, B. Wu, Y. Chen, and W. Zhang, Physical Review Letters **133**, 100401 (2024).

Day 1 Oct-14 2025
Session 3 Oral Talk O-05 14:47-14:59

Quantum and Nonlinear Cavity Magnomechanics

Jie Li[1],
[1]School of Physics, Zhejiang University, Hangzhou, China

The past decade has witnessed a fast development in the field of cavity magnonics based on collective spin excitations (magnons) in ferrimagnetic materials, such as yttrium iron garnet. As one of the prominent advantages, ferrimagnetic magnons show an excellent ability to coherently couple with various quantum systems, such as microwave photons, optical photons, phonons, and superconducting qubits. The coupling to phonons via magnetostriction forms the system of cavity magnomechanics [1], which studies the interactions among microwave cavity photons, magnons, and phonons. In this talk, I will introduce recent works we have done in the field of cavity magnomechanics, including the generation of magnon-photon-phonon entanglement [2], squeezing [3] and entanglement [4] of microwave fields, as well as rich nonlinear effects in the system, such as magnon-phonon cross-Kerr effect and mechanical bistability [5].

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[2] J. Li, S.-Y. Zhu, G. S. Agarwal. Magnon-photon-phonon entanglement in cavity magnomechanics. Phys. Rev. Lett. **121**, 203601 (2018).
[3] J. Li, Y.-P. Wang, J. Q. You, S.-Y. Zhu. Squeezing microwaves by magnetostriction. Natl. Sci. Rev. **10**, nwac247 (2023).
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[5] R.-C. Shen, J. Li, Z.-Y. Fan, Y.-P. Wang, J. Q. You. Mechanical bistability in Kerr-modified cavity magnomechanics. Phys. Rev. Lett. **129**, 123601 (2022).

Day 1 Oct-14 2025
Session 3 Oral Talk O-06 14:59-15:11

Bath-Engineering Technique for Criticality-Based Quantum Metrology with Amplitude Noise

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Quantum critical systems are extremely sensitive to parameter variation near the critical point. Moreover, the derivatives with respect to the order parameter may exhibit divergence. This quantum criticality is widely utilized to enhance the performance of quantum metrology. In this study, we take the dissipative quantum Rabi model (QRM) as an example and use the bath-engineering technique to simulate the dissipative QRM to explore the impact of the quantum criticality on the quantum metrology under dissipation. We numerically calculate the dynamics of the inverse variance of the dissipative QRM around the critical point by using the quantum-simulation method and compare our results with those obtained by the numerically exact hierarchical equations of motion (HEOM). Our simulations show that in the case of the strong dissipation or the high temperature, the precision does not exhibit divergence when approaching the point of the quantum phase transition, and the enhancement of quantum metrology by quantum criticality is relatively limited. More importantly, the quantum-simulation method based on the bath-engineering technique can accurately simulate the dynamical evolution of the critical system and consumes significantly fewer resources as compared with the HEOM. Thus, it can be an alternative solution for investigating the dynamical evolution of larger critical systems for quantum metrology.

[1] R.-H. Chen, et al., *J. Chem. Phys.* **163**, 054101 (2025).
[2] Y. Chu, et al., *Phys. Rev. Lett.* **126**, 010502 (2021).
[3] M.-J. Hwang, et al., *Phys. Rev. Lett.* **115**, 180404 (2015).
[4] A. W. Chin, et al., *Phys. Rev. Lett.* **109**, 233601 (2012).
[5] X.-Y. Long, et al., *Phys. Rev. Lett.* **129**, 070502 (2022).
[6] W.-T. He, et al., *Front. Phys.* **18**, 31304 (2023).
[7] X.-Y. Chen, et al., *npj Quantum Inf.* **8**, 22 (2022).
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Day 1 Oct-14 2025
Session 4 Oral Talk O-07 16:45-16:57

Moiré NEMS for Quantum Sensing

Xin ZHANG
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Stacking two-dimensional monolayers with rotational or lattice misalignment can form moiré superlattices, which can dramatically alter the electronic, photonic and phononic structure of the system [1]. The correlated electronic phases, such as superconductivity and Mott insulating states, may support emerging electromechanical coupling, prompting **our newly developed** [2] moiré nanoelectromechanical systems (NEMS) [3] as quantum sensors for hetero-strain, atomic reconstruction and new correlated electronic phases.

Here, we measure the vibrations of nanoelectromechanical resonators made of twisted bilayer graphene (TBG) with a moderate twist angle and observe butterfly-shaped hysteresis loops of the modal resonant frequency as a function of gate voltage which we interpret as a viscoelastic behavior [2]. We study how the frequency loops evolve as the range and the stepping rate of the gate voltage are changed. Importantly, our observations are repeatable and controllable in all of our devices. Furthermore, by continuously increasing the electrostatic pressure applied to the membrane, we find that the mechanical quality factor Q is significantly enhanced at room temperature (remarkably high value of ~1900), a counter-intuitive phenomenon we ascribe to dissipation dilution [4] that is reinforced by the reduced intrinsic dissipation. Our work introduces mechanical resonators made from moiré superlattice as promising systems for viscoelasticity engineering through rotating angles, and as dynamic probes for the emergent nanoelectromechanical couplings.

[1] E. C. Regan, et al., Nature Reviews Materials **7**, 778–795 (2022).
[2] Q. Y. Zeng, et al., Nature Communications **16**, 3793 (2025).
[3] X. Zhang, et al., Nature Communications **11**, 5526 (2020).
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Day 1 Oct-14 2025
Session 4 Oral Talk O-08 16:57-17:09

Symmetry Enriched Topological Orders and Distinct Monopole Charges for Dipole-Octupole Spin Ices

Gang Chen[1], and Pengwei Zhao[1]
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Distinct symmetry enriched topological orders often do not have classical distinctions. Motivated by the recent process on the pyrochlore spin ice materials based on the dipole-octupole doublets, we argue that dipolar spin liquid and octupolar spin liquid can be well differentiated through the magnetic charges of the magnetic monopoles in the classical spin ice regime. It is observed and predicted that, the long-range dipole-dipole interaction renders the magnetic monopole of the dipolar spin ice a finite magnetic charge via the dumbbell picture even in the classical regime. For the octupolar spin ice, however, a zero magnetic charge is expected from this mechanism in the classical regime. We expect this smoking-gun observation to resolve the debate on the nature of $Ce_2Sn_2O_7$, and more broadly, this work may inspire further experiments and thoughts on the Ce-pyrochlore spin liquids, Nd-pyrochlore antiferromagnets, Er-based spinels, and the distinct properties of the emergent quasiparticles in various symmetry enriched topological phases.

[1] Pengwei Zhao, Gang v. Chen, arXiv:**2505.07805**

ORAL TALKS

Day 1 Oct-14 2025
Session 4 Oral Talk O-09 17:09-17:21

Exploring Novel Quantum Computing Architectures in Topological Hybrid Devices

Panagiotis Kotetes
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In this talk, we address the feasibility of two prominent paths for the implementation of quantum computing using topological superconducting hybrid platforms. Firstly, we focus on topological Floquet superconducting hybrids, and develop a theoretical approach that allows to predict the arising topological phases and assess the stability of the associated Majorana zero and pi modes [1]. In particular, we prescribe how to construct the Floquet topological invariants for such driven hybrids and obtain the level broadening for the energy bands. We exemplify our approach for a Rashba nanowire coupled to a superconductor and a time-dependent Zeeman field.

Given the challenges in unequivocally pinning down the emergence of Majorana modes in existing experiments, our second direction of research aims at bringing forward novel quantum computing strategies which rely instead on topologically-protected Andreev zero modes [2]. Such modes can arise in certain superconducting hybrid systems which are invariant under time reversal operation and a subgroup of spin rotations. Despite the fact that such Andreev zero modes feature topological protection and fractionalization, they are standard fermionic excitations which allow us to define a localized two-level system. Hence, each Andreev mode can encode a single qubit, while thanks to the arising ground-state degeneracy, pairs of Andreev zero modes promise to open perspectives for braiding and non-abelian operations. Here, we propose concrete theoretical models which harbor such modes, investigate their fractionalized character, and explore the prospects of fusing and braiding them. Lastly, we discuss possible physical realizations in currently accessible hybrid devices.

[1] M. Assili and P. Kotetes, "Green Function Invariants for Floquet Topological Superconductivity", under review, submitted in July (2025).
[2] T. L. M. Lane, H. Q. Xu, and P. Kotetes, "Quantum Computing with Topological Andreev zero modes", in preparation.

Day 2 Oct-16 2025
Session 6 Oral Talk O-10 11:10-11:22

Improved Nondemolition Qubit Readout with Squeezed Light

Wei Qin
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Fast and high-fidelity nondemolition qubit readout (e.g., dispersive and longitudinal) is a prerequisite for quantum error correction and fault-tolerant quantum computation, while squeezed light is powerful resource in modern quantum technologies. It has therefore been a long-standing goal to improve nondemolition qubit readout with squeezed light [1]. However, longitudinal qubit readout can be exponentially improved by injected external squeezing (IES), but cannot by intracavity squeezing (ICE), which can avoid transmission and injection losses compared to the use of injected external squeezing (IES). More unfortunately, neither IES nor ICE can provide a significant improvement of practical interest for dispersive qubit readout. Here, I would like to introduce a protocol of using ICE to exponentially improve longitudinal qubit readout [2], and then talk about how to use IES and ICS together to exponentially improved dispersive qubit readout [3].

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Day 2 Oct-16 2025
Session 6 Oral Talk O-11 11:22-11:34

Optomechanical Dark-Mode-Breaking Cooling

Jiteng Sheng, Yan Cao, Cheng Yang, and Haibin Wu
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Optomechanical cooling of multiple degenerate mechanical modes is prevented by the mechanical dark mode due to the destructive interference. We will present the first experimental demonstration of simultaneous cooling of two degenerate mechanical modes by breaking the mechanical dark mode in a two-membrane cavity optomechanical system. The dark mode is generated as the system passes the exceptional point of the anti-parity-time symmetric scheme. By introducing a second cavity mode for the additional dissipative channel, the dark mode is broken and the total phonon number is reduced to more than an order of magnitude below the dark mode cooling limit. Owing to the flexible tunability of the optomechanical coupling rates of such a four-mode coupled system, the optimized cooling efficiency can be achieved by investigating different parameter ranges. Our results provide an important step toward to the ground state cooling and entanglement between multiple degenerate mechanical resonators.

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[4] J.-Y. Liu, W. Liu, D. Xu, J.-C. Shi, H. Xu, Q. Gong, and Y.-F. Xiao, Ground-state cooling of multiple near-degenerate mechanical modes, Phys. Rev. A **105**, 053518 (2022).

Day 2 Oct-15 2025
Session 6 Oral Talk O-12 11:34-11:46

Microwave-Optical Entanglement Dynamics in Cavity Electro-Optics

Huaibing Zhu[1], Rishabh Sahu[2], Jie Li[1], Johannes Fink[2], and Liu Qiu[1]
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Distributed quantum correlations across widely separated frequency domains are a critical requirement for hybrid quantum networks. Quantum entanglement between microwave and optical field plays a pivotal role in quantum optical networks of superconducting quantum circuits. Despite the recent demonstration of quantum correlations between microwave-optical fields, the entanglement dynamics have remained elusive. Here we show the microwave-optical entanglement dynamics of both localized and propagating field in a cavity quantum electro-optical device in mK environment. More specifically, we develop a theoretical framework and reveal experimentally the stationary and transient microwave-optical entanglement dynamics. The quantum entanglement between the spatiotemporal output propagating fields can be efficiently mapped onto localized modes within the cavity, while preserving nonclassical correlations. Our analysis further reveals the implications of experimental imperfections, e.g. internal loss, finite cavity linewidth, coupling ideality and phase uncertainty, to quantum correlations across such microwave-optical interface. Our results provide critical insights into the real-time control of quantum entanglement distribution among hybrid systems. In addition, the compatibility of our cavity electro-optical system to superconducting qubits enables wide ranges of applications in superconducting quantum networks.

Day 2 Oct-15 2025
Session 7 Oral Talk O-13 15:10-15:22

A Continuous-Wave Laser at 148 nm for the Th-229 Nuclear Clock

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The exceptionally low-energy isomeric transition in Th-229 at around 148 nm offers a unique opportunity for coherent nuclear control and the realization of an ultra-stable nuclear clock. Recent advances, most notably the incorporation of large ensembles of Th-229 nuclei in transparent crystals and the development of pulsed vacuum-ultraviolet (VUV) lasers, have enabled initial laser spectroscopy of this transition. However, the absence of an intense, narrow-linewidth VUV laser has been the critical missing element.

In this talk, I will present our proposal [1,2] and experimental realization [3] of the first continuous-wave laser at 148 nm, generated via four-wave mixing in cadmium vapor. Our source delivers 100 nW of power with a linewidth well below 100 Hz and supports broad wavelength tunability. We develop a spatially resolved homodyne technique to place a stringent upper bound on the phase noise induced by the nonlinear process and demonstrate sub-hertz linewidth capability. This development eliminates the final technical hurdle to a Th-229-based nuclear clock and opens new frontiers in quantum metrology, nuclear quantum optics and precision tests of fundamental physics.

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[2] G. Penyazkov, Y. Yu, L.V. Skripnikov and S. Ding, “Theoretical study of transition matrix elements in cadmium for vacuum-ultraviolet generation in Th-229 nuclear clock applications”. Physical Review A, 112, 022807 (2025).
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Day 2 Oct-15 2025
Session 7 Oral Talk O-14 15:22-15:34

Engineering 2D Spin Networks by On-Surface Encapsulation of Azafullerenes in Nanotemplates

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Stable molecular spins are considered as the simplest platform to encode qubits. Considerable progress has been achieved employing molecules with a transition metal as a spin-active centre. The alternative, the metal-free organic molecular systems in principle provide an excellent platform for designing large-scale architectures of molecular qubits. However, owing to their high reactivity the long-term stability of molecular organic radicals remains a major challenge in stabilisation, detection and manipulation that has yet to be satisfactorily solved, especially for extended radical arrays. This is particularly important as any complex architecture of molecular spins must ultimately be placed in some two-dimensional (2D) network on solid substrate.
Here we present an efficient strategy for on-surface engineering of organic supramolecular complexes with long-term spin protection [1]. By vacuum deposition of azafullerene ($C_{59}N^{\bullet}$) monomers [2] on a pre-deposited template layer of [10]CPP nanohoops on Au(111) surface we exploit the molecular shape matching between the $C_{59}N$• and [10]CPP for the azafullerene encapsulation. $C_{59}N^{\bullet}\subset$[10]CPP supramolecular complexes self-assemble into an extended 1D or 2D hexagonal lattice yielding a high density network of stable spin-1/2 radicals. We find compelling evidence for electronic coupling between the guest C59N$^{\bullet}$ and the host [10]CPP in supramolecular species where [10]CPP effectively protects the radical state of encapsulated $C_{59}N^{\bullet}$. Azafullerene encapsulation by nanohoops represents a viable realization of molecular spin protection while simultaneously demonstrating exceptional potential for engineering the large-scale 1D or 2D architectures of molecular qubits.

[1] G. Kladnik et al., Nat. Comm. **16**, 193 (2025).
[2] Y. Tanuma et al., ACS Nano **17**, 25301−25310 (2023).

Day 2 Oct-15 2025
Session 7 Oral Talk O-15 15:34-15:46

Non-Equilibrium Criticality-Enhanced Quantum Sensing

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Exploiting quantum features allows for estimating external parameters with precisions well beyond the capacity of classical sensors, a phenomenon known as quantum-enhanced precision. While quantum criticality has been recognized as a resource for achieving such enhancements relative to probe size, it typically requires complex probe preparation and measurement and the achievable enhancement is ultimately restricted to narrow parameter regimes. On the other hand, non-equilibrium probes harness dynamics, enabling quantum-enhanced precision with respect to time over a wide range of parameters through simple probe initialization. Here, we unify these approaches through a Stark-Wannier localization platform, where competition between a linear gradient field and particle tunneling enables quantum-enhanced sensitivity across an extended parameter regime. We also provide experimental implementation of the proposal on a 9-qubit superconducting quantum device, where we explore its performance in the extended phase, the critical point and the localized phase. Despite employing only computational-basis measurements we have been able to achieve near-Heisenberg-limited precision by combining outcomes at distinct evolution times. In addition, we demonstrate that the performance of the probe in the entire extended phase is significantly outperforming the performance in the localized regime.

References:

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[2] H. Manshouri, M. Zarei, M. Abdi, S. Bose, A. Bayat, Quantum 9, 1793 (2025)

Day 3 Oct-16 2025
Session 9 Oral Talk O-16 11:10-11:22

Superconducting Electronics for Qubit Control and Microwave Quantum State Preparation

Zhirong Lin[1]
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Superconducting circuits have demonstrated significant potential as a platform for building large-scale quantum processors. However, scaling superconducting quantum circuits to thousands of qubits within a dilution refrigerator presents considerable challenges. One of the key obstacles is the reliance on classical microwave-based control, which necessitates substantial hardware overhead at room temperature for signal generation and transmission. In this presentation, we introduce a millikelvin control technique for superconducting qubits that leverages single flux quantum (SFQ) circuitry [1, 2]. By implementing this technique, we have achieved a single-qubit fidelity of 99.9%, offering a promising solution to the challenges of scalability. Additionally, I will also highlight our latest research progress in microwave quantum optics. We demonstrate the rapid generation of Schrödinger cat states using a Kerr-tunable SNAIL resonator [3] and show how to precisely control microwave field with tunable collective quantum states in waveguide-coupled Bragg and anti-Bragg superatoms [4].

[1] K. Liu et al., Physical Review B **108**, 064512 (2023).
[2] Y. F. Wang et al. Physical Review Applied **19**, 044031 (2023).
[3] X. L. He, Yong Lu, D. Q. Bao, Hang Xue, W. B. Jiang, Z. Wang, A. F. Roudsari, Per Delsing, J. S. Tsai & Z. R. Lin, Nature Communications **14**, 6358 (2023).
[4] Z. Niu, W. Nie, D. Bao, X. He, W. Gao, K. Liu, I.-C. Hoi, Yu-xi Liu, X. Xie, Z. Wang, Z. R. Lin, arXiv: 2507.00935

Day 3 Oct-16 2025
Session 9 Oral Talk O-17 11:22-11:34

Two-Qubit Gate Error Revisited for Non-Markovian Noise

Ruixia Wang[1], Jiayu Ding[1], and Fei Yan[1]
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Quantum gate fidelity is a critical performance determinant in quantum information processing. Environmental noise adversely affects the fidelity of quantum gates, with varying impact depending on the spectral characteristics of the noise. In this study, we analyze the frequency-domain response of two-qubit gates to non-Markovian noise and derive analytical expressions quantifying how noise at specific frequencies influences gate fidelity. We design experimental protocols to test these theoretical predictions and observe excellent agreement between experimental data and model outputs. Our findings clarify the role of the noise spectrum in gate infidelity via its coupling with two-qubit interaction strengths. This work offers an analytical framework for understanding the coherence limits of two-qubit gates in the presence of structured noise, thereby providing insights and practical considerations for enhancing gate performance.

Day 3 Oct-16 2025
Session 9 Oral Talk O-18 11:34-11:46

Analytical Control for Quantum Computation and Simulation

Boxi Li[1], Francisco Cárdenas-López[1], Tommaso Calarco[1,2] and Felix Motzoi[1,2],
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[2] Institute for Theoretical Physics, University of Cologne, D-50937 Cologne, Germany

The rapid advancement of quantum technologies has made precise control over complex quantum systems both a central challenge and a critical enabler for scalable quantum applications. As systems grow in size and complexity, quantum control techniques must evolve to remain effective under realistic physical constraints. While numerical optimal control approaches can yield high-fidelity gates, they often suffer from computational inefficiency, sensitivity to model inaccuracies, and limited interpretability. In contrast, analytical control methods, built on a deep understanding of system dynamics, often provide simple and compact drive schemes, particularly suitable for experimental calibration in today's hardware.

In this talk, I will present a framework for analytical quantum control based on separating system dynamics into resonant and adiabatic components. This perspective allows us to interpret common errors, such as leakage and crosstalk, as manifestations of nonadiabatic transitions [1]. I will show how these errors can be systematically suppressed using Counterdiabatic Driving techniques such as the Derivative Removal by Adiabatic Gate (DRAG) method [2,3]. We will discuss how these techniques have been extended to suppress multiple error channels simultaneously, resulting in high-fidelity operations in single-qubit, two-qubit and multilevel (qudit) systems [4–6]. I will also outline how this analytical framework connects to the design of efficient quantum simulation protocols, especially in strongly driven regimes where nonperturbative effects play a critical role [7].

[1] B. Li, Forschungszentrum Jülich, 2025.
[2] F. Motzoi, J. M. Gambetta, P. Rebentrost, and F. K. Wilhelm, Phys. Rev. Lett. **103**, 110501 (2009).
[3] L. S. Theis, F. Motzoi, S. Machnes, and F. K. Wilhelm, EPL **123**, 60001 (2018).
[4] B. Li, T. Calarco, and F. Motzoi, Npj Quantum Inf **10**, 1 (2024).
[5] B. Li, F. A. Cárdenas-López, A. Lupascu, and F. Motzoi, arXiv:2412.18339.
[6] R. Wang, Y. Feng, Y. Zhang, J. Ding, B. Li, F. Motzoi, Y. Gao, H. Xu, Z. Yang, W. Nuerbolati, H. Yu, W. Sun, and F. Yan, arXiv:2502.10116.
[7] D. Sels and A. Polkovnikov, Proc. Natl. Acad. Sci. U.S.A. **114**, E3909 (2017).

Day 3 Oct-16 2025
Session 10 Oral Talk O-19 15:10-15:22

Efficient Pulse-Level Recompilation of Quantum Circuits: Jenga-Krotov Algorithm and Beyond

Sunny Xin Wang[1], Jiahao Wu[1], Fei Dai[1], and Jie Liu[1],
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As quantum devices move toward practical utility, pulse-level recompilation offers a powerful route to bridge abstract circuit models and hardware-native operations. In this talk, we present three recent advances that collectively enhance gate efficiency, robustness, and learnability. We begin with the Jenga-Krotov (JK) algorithm, a hybrid gradient-based approach tailored for exchange-only qubits, which synthesizes compact, high-fidelity multi-qubit gates with significant reductions in circuit depth and noise sensitivity [1]. Next, we introduce the Error-Resilient Gate Compilation (ERGC) protocol, which constructs arbitrary single-qubit gates using fixed-angle X rotations and optimized Z-phase sequences [2]. ERGC is experimentally friendly—leveraging virtual-Z gates—and exhibits strong resilience against quasi-static noise and crosstalk. Finally, we present the inverse Physics-Informed Neural Network framework (iPINN-HL), which reformulates Hamiltonian learning as a PDE-constrained inverse problem [3]. By embedding Schrödinger dynamics into the learning loop, iPINN-HL achieves high-accuracy characterization under realistic sampling constraints. Together, these methods provide a coherent and flexible approach to pulse-level compilation, with implications for quantum control, calibration, and scalable architecture design.

[1] J. Wu, G. He, W. Zhuo, Q. Fu, and X. Wang, arXiv:2507.12448 (2025).
[2] F. Dai et al., in prepration.
[3] J. Liu, and X. Wang, arXiv:2506.10379 (2025).

Day 3 Oct-16 2025
Session 10 Oral Talk O-20 15:22-15:34

Toward Scalable, High-Fidelity Fluxonium-Based Quantum Devices

Lijing JIN[1]
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The fluxonium qubit has emerged as a compelling candidate for superconducting quantum computing, owing to its long coherence times, strong anharmonicity, and rich energy spectrum. In small-scale systems, fluxonium has already achieved two-qubit gate fidelities exceeding 99.9%, setting a new benchmark for superconducting qubits. However, scaling up such performance to larger systems remains a central challenge to establishing fluxonium as a viable alternative to the transmon. A key open problem is how to realize a scalable fluxonium processor that preserves high-fidelity operations.

We present a scalable fluxonium processor architecture that integrates tunable-transmon couplers. Our implementation achieves parallel single-qubit gate fidelities up to 99.99%, an average simultaneous two-qubit gate fidelity of approximately 99%, and best-case two-qubit gate fidelities reaching 99.9%. Furthermore, the rich energy spectrum of fluxonium offers additional degrees of freedom for mitigating frequency crowding in large-scale devices. These results demonstrate the promise of fluxonium-based architectures as a scalable, high-fidelity platform for fault-tolerant quantum computing.

Day 3 Oct-16 2025
Session 10 Oral Talk O-21 15:34-15:46

Sources of Decoherence in Qubits Based on Disorder Superconducting Materials

Feng Wu[1]
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Superconducting platform is one of the compelling realizations of quantum computing. Introducing disorder in the superconducting materials is promising to enhance the impedance to realize noise-resilient qubits, but the performance is still limited by decoherence. To address this, we develop a systematic method to characterize errors in superconducting qubits and successfully identify prominent errors sources in devices based on different materials. In Al-based fluxonium qubits, dielectric loss is the predominant factor influencing dissipation, while 1/f flux noise primarily determines dephasing. At low frequencies below 100 MHz, 1/f flux noise can also significantly contribute to dissipation. In contrast, for disordered Ti-Al-N based fluxonium qubits, 1/f flux noise dominates both dissipation and dephasing up to GHz frequencies. Based on the decoherence model, we suggest that an intrinsic bulk property of the disorder material dominates the decoherence, in contrast to surface defects in other qubits.

[1] Gao, R. et al. The effects of disorder in superconducting materials on qubit coherence. Nat Commun 16, 3620 (2025).
[2] Sun, H. et al. Characterization of Loss Mechanisms in a Fluxonium Qubit. Phys. Rev. Appl. 20, 034016 (2023).

ORAL TALKS

POSTER LIST

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1. Tomography-Assisted Noisy Quantum Circuit Simulator Using Matrix Product Density Operators
Weiguo Ma | Institute of Physics, CAS

2. Few-photon-level Coherent Manipulation of a Quantum Dot in Low-Reflectivity Micropillar Cavity
Jiajun Wang | BAQIS

3. Direct Implementation of High-Fidelity Three-Qubit Gates for Superconducting Processor with Tunable Couplers
Haotian Liu | Institute of Physics, CAS

4. Computational Discrete Global Geometric Structures for Quantum Understanding
Hui Zhao | The Lab of Computational Discrete Global Geometric Structures

5. A Single-Photon Source Based on Topological Bulk Cavity
Xinrui Mao | BAQIS

6. Scalable Low-Overhead Superconducting Non-Local Coupler for Circuit Connectivity Enhancement
Haonan Xiong | BAQIS

7. ErrorGnoMark: A Modular Framework for Systematic Benchmarking and Multi-Level Noise Characterization of Quantum Processors
Xudan Chai | BAQIS

8. Noisy Probabilistic Error Cancellation and Generalized Physical Implementability
Tianren Jin | Institute of Physics, CAS

9. An Analytical Investigation of a Two-Electron Quantum Dot in a Quartic Anharmonic Potential
Soumen Das | Visva Bharati

10. Two-Photon Interference between Mutually-Detuned Resonance Fluorescence Signals Scattered off a Semiconductor Quantum Dot
Ziqi Zeng | BAQIS

11. Quantum Compiling with Reinforcement Learning on a Superconducting Processor
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12. Stabilizer Rényi Entropy for Translation-Invariant Matrix Product States
Lei-Yi-Nan Liu | Beihang University

13. Survival and Detection of Symmetry-Protected Topology in Loop Quenches
Miklos Horvath | BAQIS

14. Superior Frequency Stability and Long-Lived State-Swapping in Cubic-SiC with Degeneracy-Broken Mechanical Modes
Huanying SUN | BAQIS

15. Genuine Entanglement Criteria for Four Mode Continuous Variable System
Xiao-Yu Chen | Hangzhou City University

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Yang Gao | BAQIS

17. Non-Hermitian Superconducting Diode Effect
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18. Mitigating Measurement Crosstalk via Pulse Shaping
He Wang | BAQIS

19. Observation of Average Topological Phase in Disordered Rydberg Atom Array
Zongpei Yue | Tsinghua University

20. Optimal Control of Unknown Collective Spin Systems via a Neural Network Surrogate
Yaofeng Chen | Tsinghua University

21. Generating Large-Scale GHZ-Like States in Lattice Spin Systems
Xuanchen Zhang | Tsinghua University

22. Novel Ground States and Emergent Quantum Many-Body Scars in a Two-Species Rydberg Atom Array
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23. Long-Distance Spin Transport in Frustrated Hyperkagome Magnet $Gd_3Ga_5O_{12}$
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24.Superconducting Quantum Simulation and Quantum Computing with Tunable Couplings
Yun-Hao Shi | Institute of Physics, CAS

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Ruiqi Cao | BAQIS

28. Low-Noise Large-Bandwidth High-Gain Transimpedance Amplifier for Cryogenic STM
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30. Microscopic Mechanisms of Exciton Polariton Relaxation in Monolayer WS_2 Microcavities
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31. Correlated Photon-Pair Source Using Silicon Microring Enhanced by Reverse-Biased Free-Carrier Depletion
Qiang Zeng | BAQIS

32. Efficient Quantum Circuit Compilation for Near-Term Quantum Advantage
Shuo Yang | Tsinghua University

33. Scalable Atomic-Precision Synthesis of MoS_2-WS_2 Lateral Heterostructures for Tailored Optoelectronics
Yibiao Feng | Beijing Normal University

34. Simulation of One and Two-Qubit Superconducting Quantum Gates under the Non-Markovian 1/f Noise
Yinjia Chen | Institute of Chemistry Chinese Academy of Sciences

35. Optomagnonic Continuous-Variable Quantum Teleportation Enhanced by Non-Gaussian Distillation
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36. Topological Phases in Open Quantum Systems
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38. Green Function Invariants for Floquet Topological Superconductivity Induced by Proximity Effects
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39. High-Density Wiring Solution for 500-Qubit Scale Superconducting Quantum Processors
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Hao Li | BAQIS

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44.Realization of High-Fidelity Perfect Entanglers between Remote Superconducting Quantum Processor
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50. Experimental Realization of Criticality-Enhanced Global Quantum Sensing via Non-Equilibrium Dynamics
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51. Fast Transverse Mode Gate with Trapped Ions
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52. Simulating Light-Assisted Collision Process in Optical Tweezers of ^{171}Yb
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54. Contaminated Quntum Readout Error Mitigation
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55. Manipulations of a Quantum Optomechanical Device via Microwave Photonics
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60.A Resource-Virtualized and Hardware-Aware Quantum Compilation Framework for Real Quantum Computing Processors
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62. Hamiltonian Learning via Inverse Physics- Informed Neural Network
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63. Spin Coherence Times of Eu Ions Doped in Thin Membranes of Y_2SiO_5 Crystal
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64. Threshold-Less and Flexibly Tunable Frequency Comb via Cavity Floquet Engineering
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65. Quantum Enhanced Hazardous Substances Surveillance System
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66. Degeneracy-Breaking and Long-Lived Multimode Microwave Electromechanical Systems Enabled by Cubic Silicon-Carbide Membrane Crystals

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67. Lattice-Based Access Authentication Scheme for Quantum Communication Networks
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70. Quantum Computing with Topological Andreev Zero Modes
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71. Tunable Wigner Molecules in a Germanium Quantum Dot
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73. Superconducting Qubit Control Chip Based on SFQ Circuitry at Millikelvin Temperatures
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74. Light Manipulation via Tunable Collective Quantum States in Waveguide-Coupled Bragg and Anti-Bragg Superatoms
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75. A Jenga-Krotov Method for Efficient Pulse-Level Optimization of Quantum Algorithms
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76. Development of Fused Silica Monolithic Trap for Two-Dimensional Ion Crystal
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77. Quantum-Classical Gravity Distinction in Reservoir-Engineered Massive Quantum System
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78. Programmable Anyon Mobility Through Higher Order Cellular Automata
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79. Fast, Simple All-Microwave Two-Qubit Gate Scheme Based on Autler-Townes Effect
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80. Tunable Superconducting Diode Effect in Higher-Harmonic InSb Nanosheet Interferometers
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81. Charge-Parity Detection Based on Controlling the Gate Voltage of a Transmon Qubit
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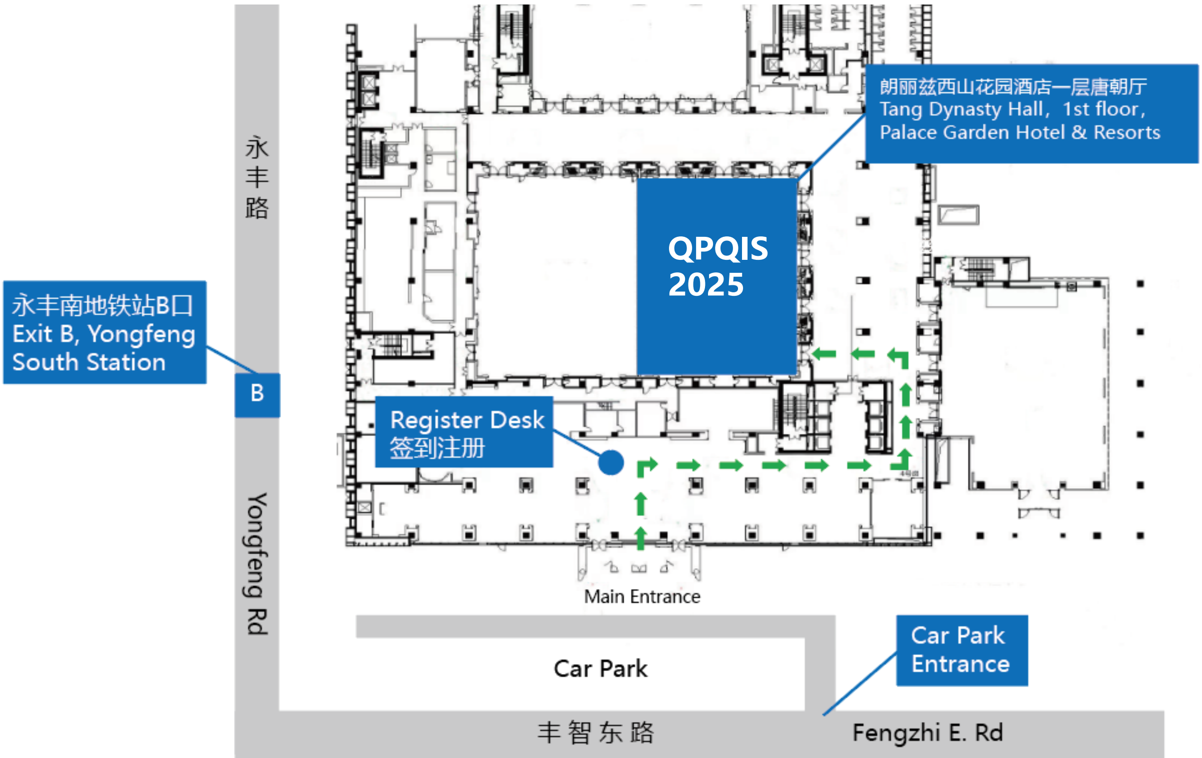

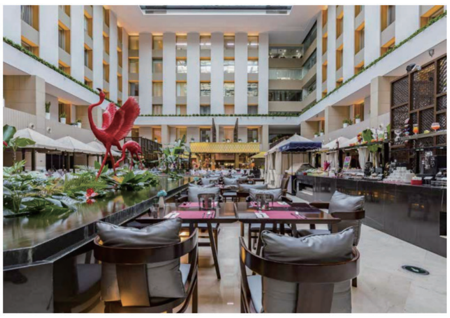

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