Solid State Systems for Quantum Information Processing International Workshop (SQuIP)

June 8, 2026 - June 12, 2026

Invited and short talk schedule with abstracts

Monday, June 8

10:15–11:00

- Fernando Gonzalez-Zalba (CIC nanoGUNE & Quantum Motion, Spain/UK)
  Title: Recent advances in readout of semiconductor spin qubits
  Abstract:
  M. Fernando Gonzalez-Zalba
  Ikerbasque Research Professor at CIC nanoGUNE
  Principal Quantum Engineer at Quantum Motion Technologies

  Semiconductor spin qubits are one of the most promising hardware platforms for large-scale quantum computing. Particularly, electron spins in silicon-based quantum processors have demonstrated high-fidelity qubit initialisation, measurement, and single- and two-qubit control with fidelities exceeding the 99% threshold required to implement quantum error correction. More recently systems have been scaled up from small 2-qubit devices to 18-qubit quantum processors where repeated syndrome measurements have been performed. Notably, such silicon-based quantum processors can be fabricated using industrial manufacturing techniques and integrated with cryogenic electronics, offering a promising route to scaled quantum computing. However, readout of such qubits remains the longest of all operational steps and the one requiring the largest infrastructure hence new advancements are needed.

  In this talk, I will briefly review the state-of the-art and scaling challenges ahead for silicon-based quantum computing [1] to then focus on our recent work on electron spin qubit devices fabricated using 300-mm wafer processes. Particularly, I will focus on recent advances on readout including: (i) the demonstration of ultra-compact and non-linear rf readout sensors based on high kinetic inductance elements [2], (ii) the operation of a compact single-electron box for high-fidelity spin readout [3], (iii) the demonstration of a new dispersive sensing method, the rf electron casade [4] and (iv) the integration of a millikelvin multiplexer for rapid characterisation of 1000+ quantum devices [5].

  References

  [1] M.F. Gonzalez-Zalba et al. Nat Electron 4 872-884 (2021)

[2] T. Swift et al. arxiv:2507.1302 (2025)

[3] C. Laine et al. arxiv:2505.10435 (2025) accepted Nat Sensors (2026)

[4] J. Chittock-Wood et al. Nat Electron 9 314-323 (2026)

[5] E. Thomas, Nat Electron 8 75-83 (2025)

11:00–11:45

- Anthony Sigillito (University of Pennsylvania, USA)
  Title: Fast, electrical control of multielectron Si-MOS spin qubits via intrinsic spin-orbit coupling
  Abstract:
  Silicon-MOS spin qubits offer high fidelity control via magnetically driven electron spin resonance (ESR) using on-chip transmission lines or through electric dipole spin resonance (EDSR) via on-chip micromagnets. However, magnetic control approaches can be slow and prone to crosstalk, whereas EDSR leads to enhanced sensitivity to charge noise, limiting coherence. Recent efforts have demonstrated micromagnet-free EDSR in Si quantum dot devices by utilizing valley or orbital degeneracy points, but these methods require careful device tuning. Here we demonstrate a tuning-insensitive approach where all-electrical spin control is mediated by intrinsic spin-orbit coupling (SOC) in single and multi-electron quantum dots.

  In this work, we study a single quantum dot (SQD) spin qubit driven by both magnetic and electric fields. We map out Rabi frequency as a function of electron occupation in the SQD and show that higher occupancy can offer faster Rabi oscillations. We investigate the coherence and relaxation times and find a net benefit to operating in the multielectron regime. We further characterize gate fidelities using randomized benchmarking and gate set tomography. Fidelity limitations are still under investigation but preliminary results will be discussed. These results represent one of the first demonstrations of all-electric spin control of foundry-fabricated MOS devices via intrinsic SOC. Noise mitigation strategies and future directions will also be discussed.

13:15–14:00

- Thaddeus Ladd (HRL Laboratories, USA)
  Title: A digitally controlled silicon quantum processing unit
  Abstract:
  Commercially-relevant quantum computers will require large numbers of high-performing qubits that can be manufactured, integrated, and controlled at scale. Silicon exchange-only (EO) qubits are a strong candidate modality due to their control-signal simplicity and compatibility with advanced semiconductor

manufacturing, but questions remain around the achievability of sufficiently low noise and a scalable control and wiring solution. Here we introduce a quantum processing unit composed of a custom-designed cryogenic CMOS controller, a novel high-density superconducting ribbon cable, and a low-noise EO qubit device. The quantum chip features a three-rail array of 54 exchange-coupled quantum dots, configurable to host up to 18 EO qubits. We integrate and use these components to demonstrate qubit performance for both single-qubit and entangling operations that advances the EO state of the art by an order of magnitude. We further validate this system by implementing a distance-5 repetition code and a quantum error detecting code then make detailed comparisons with simulations. Our approach facilitates a utility-scale quantum computer with manageable operational and capital requirements.

14:00–14:45

- Tanner Janda (University of California, Los Angeles, USA)
  Title: Molecular spectroscopy and scalable microwave control of Si/SiGe spin qubits
  Abstract:
  High-fidelity operation of silicon spin qubits requires a comprehensive understanding of the underlying energy level structure as well as precise control of the spin state. Thoroughly characterizing the many energetic degrees of freedom of a double quantum dot system allows for reliable qubit control and readout techniques, such as Pauli spin blockade and electric dipole spin resonance. Typical energetic probes such as cavity-based or pulsed gate spectroscopy only allow the measurement of these energies at narrow windows of parameter space. In the first half of this talk, we will discuss a new spectroscopic method which can be used to visualize the energy spectrum of a double quantum dot molecule over a vast range of parameter space [1]. In the second half of this talk, we will discuss a separate study which focused on the nonlinear effects of microwave electrical control of single-spin qubits in Si/SiGe [2]. The results of this study allow us to further understand limiting factors on single qubit fidelities when scaling Si/SiGe spin qubits.

  [1] H. M. Yoo, T. M. Janda, C. Nasseraddin, and J. R. Petta, Directly visualizing the energy level structure of quantum dot molecules (2026), arXiv:2604.00232.

  [2] T. M. Janda, H. M. Yoo, C. Nasseraddin, A. R. Mills, Z. J. Zheng, and J. R. Petta, Microwave response of electrically driven spins in a three-qubit quantum processor (2026), arXiv:2603.08577.

14:45–15:30

- Mayer Feldman (Intel Corporation, USA)
  Title: Scaling Spin Qubits in Silicon
  Abstract:
  In the past two decades, quantum computing with spin qubits in silicon has seen an explosion of progress. From high fidelity control, measurement, cryocontrol, and foundry compatible device demonstrations spin qubits in silicon have become a forerunner in the race to build a fault-tolerant quantum computer. A successful fault tolerant quantum computer requires many pieces to work in concert with one another. From the fabrication, materials, physical system, control and analysis, each piece must be developed in tandem. Any failure of these pieces will reduce the operation fidelity of the processor and put error correction at risk. This talk will be focused on Intel's efforts in all of these parts and demonstrate that there is a clear path to scale our quantum processors built using Intel 18A both in size while increasing performance.

16:00–17:00 (Short Talks)

- Giovanni Francesco Diotallevi (University of Augsburg, Germany)
  Title: The role of electric fields in semiconductor hole spin-qubits
  Abstract:
  Hole spin qubits in group-IV semiconductors, particularly Ge, are a leading platform for spin-based quantum computing due to their strong, gate-tunable spin–orbit interaction, which enables fast, fully electrical control and high-fidelity operations. Despite this progress, the role of electric fields in determining the fundamental properties of Ge hole-spin qubits remains partially not understood.

  In this work, we study two underexplored effects of electric fields in Ge quantum dots. First, via a perturbative reduction of the four-band Luttinger–Kohn Hamiltonian, we analyse the effects that static electric fields can provide in tuning the effective mass and g-factor of heavy-hole quasiparticles. Second, we develop a Floquet-based effective theory to analyze the impact of high-frequency electric driving on heavy–light hole mixing. This approach demonstrates how tailored oscillating fields can dynamically modulate spin–orbit interaction, offering new strategies to mitigate charge-noise-induced decoherence and unwanted cross-talk.

- Manuel Guatto (Forschungszentrum Juelich, Germany)
  Title: Real-time adaptive quantum error correction by model-free multi-agent learning
  Abstract:

Can Quantum Error Correction (QEC) adapt in real time to changing noise? We show that it can. We introduce a two-level reinforcement learning framework that learns QEC from scratch and adapts it on the fly. At the first level, a model-free multi-agent RL system automatically discovers full QEC cycles*encoding, stabilizer measurements, and recovery*using only orthogonality constraints and no prior knowledge of the device. Using the stabilizer formalism, we demonstrate that it can generate new QEC codes tailored to multi-level quantum architectures. At the second level, we present BRAVE (Bandit Retraining for Adaptive Variational Error correction), an efficient algorithm that continuously retunes the variational layer to track time-dependent noise with minimal retraining. Combined, these methods yield more than an order-of-magnitude improvement in logical fidelity under time-varying bit- and phase-flip noise compared to standard QEC schemes.

17:30–17:55 (SIP Industry Session)

- Hiroyuki Moriya (NTT Corporation, Japan)
  Title: Nonreciprocal propagation of surface acoustic wave induced by magnon-phonon coupling in a single magnetic layer
  Abstract:
  Hiroyuki Moriya1*, Motoki Asano1, Daiki Hatanaka1, Yoshitaka Taniyasu1,

  Hajime Okamoto1, and Hiroshi Yamaguchi1

  1Basic Research Laboratories, NTT, Inc., Japan

  We present nonreciprocal propagation of surface acoustic wave (SAW) using magnon-phonon coupling in a single magnetic layer. A directional difference in SAW transmission appears when the magnetic field is applied perpendicular to the wave propagation direction, reaching 25 dB/mm, which is the largest value reported for devices employing a single magnetic layer. The observed behavior can be explained by the direction-dependent mode overlap, rather than by the conventional mechanism of nonreciprocity [1, 2]. This finding provides an alternative approach for realizing nonreciprocal phonon propagation.

  References

  1. M. Weiler et al., Phys. Rev. Lett. 106, 117601 (2011).

  2. M. Küß et al., Phys. Rev. Appl. 15, 034060 (2021).

Tuesday, June 9

09:00–09:45

- Fedor Jelezko (University of Ulm, Germany)
  Title: Optically addressable spin systems for light-matter quantum interfaces
  Abstract:
  Realisation of efficient quantum memory coupled to photons is essential for quantum communication and scalable quantum information processing. We will demonstrate high fidelity optical readout and coherent control of quantum registers based on single GeV colour centres in diamond. Coherent control of quantum memories based on nuclear spins allowing to reach long coherence times will be demonstrated. We will also discuss the application of optically active organic molecules for the realisation of a spin-photon quantum interfaces.

10:15–11:00

- Michael Trupke (Austrian Academy of Sciences, Austria)
  Title: Quantum technology with spin centres in crystals
  Abstract:
  Michael Trupke

  Austrian Academy of Sciences, IQOQI-Vienna, Boltzmanngasse 3, 1090 Vienna, Austria

  Nitrogen-vacancy (NV) centres in diamond are at the forefront of the development towards devices for quantum sensing. The sensitivity of most systems is limited by the spin contrast and by the collection of photoluminescence. I will present a method to improve the spin contrast by tailoring the optical initialization to the NV's ionization cycle1. I will also describe progress on electrical readout, which allows to circumvent optical collection, with a view to enhanced state readout compatible with high-end CMOS electronics2,3.

  For quantum photonics, other systems are being explored in search of better optical properties. Vanadium in SiC has emerged as a strong candidate for these applications4–9: It has a strong optical transition at 1.3 μm, compatible with optical fiber networks, a long-lived electron spin, and is hosted in a material that is available with high quality at an industrial scale. Significant advances have been made in our understanding of this system, the control of its electron spin, and the development of photonic interfaces for quantum networks10. Its long spin lifetime, the high-dimensional nuclear spin, and the narrow inhomogeneous distribution of transition frequencies render this spin centre particularly suitable

for a spin-based quantum technology platform with photon-mediated entanglement operations7,11.

References

1. D. WIRTITSCH et al., “Exploiting ionization dynamics in the nitrogen vacancy center for rapid, high-contrast spin, and charge state initialization,” Phys. Rev. Research 5 1, 013014 (2023); https://doi.org/10.1103/PhysRevResearch.5.013014.

2. M. GULKA et al., “Room-temperature control and electrical readout of individual nitrogen-vacancy nuclear spins,” Nat Commun 12 1, 4421 (2021); https://doi.org/10.1038/s41467-021-24494-x.

3. D. WIRTITSCH et al., “Microelectronic readout of a diamond quantum sensor,” arXiv (2024); https://doi.org/10.48550/ARXIV.2403.03090.

4. L. SPINDLBERGER et al., “Optical Properties of Vanadium in 4 H Silicon Carbide for Quantum Technology,” Phys. Rev. Applied 12 1, 014015 (2019); https://doi.org/10.1103/PhysRevApplied.12.014015.

5. C. M. GILARDONI et al., “Hyperfine-mediated transitions between electronic spin-1/2 levels of transition metal defects in SiC,” New J. Phys. 23 8, 083010 (2021); https://doi.org/10.1088/1367-2630/ac1641.

6. B. TISSOT et al., “Nuclear spin quantum memory in silicon carbide,” Phys. Rev. Research 4 3, 033107 (2022); https://doi.org/10.1103/PhysRevResearch.4.033107.

7. T. ASTNER et al., “Vanadium in silicon carbide: telecom-ready spin centres with long relaxation lifetimes and hyperfine-resolved optical transitions,” Quantum Sci. Technol. 9 3, 035038 (2024); https://doi.org/10.1088/2058-

9565/ad48b1.

8. P. KOLLER et al., “Strain-enabled control of the vanadium qudit in silicon carbide,” Phys. Rev. Materials 9 4, L043201 (2025); https://doi.org/10.1103/PhysRevMaterials.9.L043201.

9. P. CILIBRIZZI et al., “Ultra-narrow inhomogeneous spectral distribution of telecom-wavelength vanadium centres in isotopically-enriched silicon carbide,” Nature Communications 14 1, 8448 (2023); https://doi.org/10.1038/s41467-

023-43923-7.

10.J. FAIT et al., “High finesse microcavities in the optical telecom O-band,” Appl. Phys. Lett. 119 22, 221112 (2021); https://doi.org/10.1063/5.0066620.

11.K. NEMOTO et al., "Photonic Architecture for Scalable Quantum Information Processing in Diamond," Physical Review X 4 3 (2014); https://doi.org/10.1103/PhysRevX.4.031022.

11:00–11:45

- Nir Bar-Gill (Hebrew University of Jerusalem, Israel)
  Title: Quantum coherence and control in Diamond
  Abstract:
  The study of quantum coherence, dynamics and the development of novel quantum technologies has been a long-standing goal in quantum information science.

  In this talk I will address these topics through the platform of nitrogen-vacancy (NV) spins in diamond, which have emerged over the past several years as well-controlled quantum systems, with promising applications ranging from quantum information science to magnetic sensing.

  I will present a general theoretical framework we developed for Hamiltonian engineering in an interacting spin system. This framework is applied to the coupling of the spin ensemble to a spin bath, including both coherent and dissipative dynamics. Using these tools, I will present our recent results on enhanced coherence in many-body spin systems, surpassing the current state-of-the-art and providing a path toward studies of disordered many-body spin problems and applications in quantum technologies, such as enhanced sensing.

  I will also describe our recent work on optimal quantum transport in dissipative, disordered spin systems. Motivated by experimental efforts toward the creation of mesoscopic spin baths through local implantation, we studied and identified emergent timescales for transport in spin networks with dephasing. These results could lead to optimized transport regimes and eventually to spin buses for quantum information transfer.

14:45–15:30

- Stephen Lyon (Princeton University, USA)
  Title: Efficient Parallel Shuttling of Electron Spin Qubits Above Helium-filled Micro-Channels
  Abstract:
  Some key potential advantages of electron spin qubits over other quantum processor technologies are that electrons are small, light, and highly mobile. Charge-coupled devices (CCDs) have demonstrated GHz speeds in semiconductors, and are capable of moving many electrons - 100s of millions - simultaneously over prescribed paths with only a few control lines. They thus

naturally lend themselves to highly parallel quantum computing architectures. However, moving electrons inside a semiconductor introduces the possibility of spin decoherence through the spin-orbit interaction. Shuttling electrons across a superfluid helium surface is expected to largely eliminate this decoherence, and I will discuss calculations which show that spin-orbit decoherence is negligible for electrons bound to helium. I will also discuss experiments demonstrating the choreographed motion of about 4000 small electron packets (down to an average of 1 electron per packet) in a device which was produced in a CMOS foundry. Additionally, I will show recent results in which individual electrons have been isolated, and then shuttled along paths for millimeters in another foundry fabricated device. These results establish the viability of shuttling large arrays of individual electron spin qubits in this technology.

15:30–16:15

- Lars Schreiber (RWTH Aachen University, Germany)
  Title: Scalability with conveyor-belt spin-qubit shuttling in Si/SiGe
  Abstract:
  Lars R. Schreiber1,2

  1JARA-FIT Institute for Quantum Information, Forschungszentrum Jülich GmbH and

  RWTH Aachen University, Germany

  2ARQUE Systems GmbH, Germany

  Conveyor-belt shuttling transports single electron spin qubits adiabatically in a propagating sinusoidal potential defined by gate electrodes in a Si/SiGe quantum channel [1]. This approach relies on purely electrical control with only a few tunable signals [2] and is compatible with industrial fabrication processes [3]. Importantly, the electron spin state can be preserved during transport in Si/SiGe devices [4]. Mobile spin qubits enable new approaches to qubit manipulation, reduce cross-talk and might enhance the spin qubit connectivity [5].

  I discuss integrating mobile qubits into sparse quantum-computing architectures compatible with cryogenic electronics. To fully exploit spin-qubit shuttling, linear shuttle lanes must be extended into two-dimensional grids with controllable electron routing. I show how T-junctions between shuttle lanes can be realized without additional control lines [6]. I further present how conveyor-mode shuttling can generate two-dimensional maps of local material properties [7], including electrostatic disorder, valley splitting, and complex intervalley coupling, providing feedback for mitigation strategies and benchmarking material improvements [8,9,10].

[1] Langrock et al. PRX Quantum 4, 020305 (2023).

[2] Xue et al. Nat. Commun. 15, 2296 (2024).

[3] Muster et al. IEEE IEDM (2025). DOI: 10.1109/IEDM50572.2025.11353490

[4] Struck et al. Nat. Commun. 15, 1325 (2024); De Smet et al. Nat. Nanotech. 20, 866 (2025).

[5] Boter et al. Phys. Rev. Appl. 18, 024053 (2022); Kuenne et al. Nat. Commun. 15, 4977 (2024).

[6] Beer et al. arXiv:2601.03942 (2026).

[7] Volmer et al. npj Quantum Inf. 10, 61 (2024).

[8] Volmer et al. arXiv2510.03773 (2025).

[9] Volmer et al. arXiv:2603.01844 (2026).

[10] Rahlff et al., arXiv:2605.31358 (2026).

16:45–17:30

- Yuta Matsumoto (Delft University of Technology, Netherlands)
  Title: Semiconductor Spin Shuttling for High-Speed Quantum Gates and Reconfigurable Connectivity
  Abstract:
  Spin qubits in semiconductor quantum dots present a promising pathway toward scalable quantum computation, with recent demonstrations of high-fidelity gates. However, connectivity is so far limited to nearest neighbors in a lattice, constraining the design of large-scale processors. Long-range coherent links between spin-qubit registers could relax constraints on crosstalk and fanout, enable sparse processor architectures, and facilitate integration with classical control electronics [1]. Transport-based architectures, where qubits are physically shuttled, offer a route to reconfigurable connectivity while enabling new modes of high-speed quantum control.

  This talk presents recent advances in coherent spin shuttling using "conveyor-mode" transport, where traveling-wave potentials move electrons smoothly through a channel. We demonstrate phase-coherent spin transport by back-and-forth shuttling up to 10 μm in total with 99.5% fidelity. While micrometer-scale shuttling links have recently been demonstrated in germanium and silicon [2,3], long-distance phase-coherent shuttling in silicon remains a key challenge. Most recently, we demonstrated long-distance phase-coherent spin transport in silicon, achieving 98% fidelity across a 10 μm Si/SiGe conveyor channel composed of 143 shared-control gates.

Building on this foundation, I discuss how conveyor-mode transport can be extended from coherent spin transfer to quantum-computing primitives, focusing on three developments. First, we demonstrate exchange interactions between mobile spins confined in separate traveling-wave potentials, enabling a ~99% fidelity CZ gate and quantum state teleportation over a four-dot separation [4]. Second, I discuss operation at lower magnetic fields, where conveyor-based motion enables single-spin control through resonant electric-dipole spin resonance or spin-diabatic shuttling through regions with a quantization-axis tilt. Third, I show how quantization-axis tilts combined with shuttling-velocity control enable switchable high-speed two-qubit gates: adiabatic shuttling yields a CZ or SWAP gate, while diabatic shuttling generates a CX gate through reference frame changes.

Together, these results establish semiconductor spin shuttling as a versatile platform for combining coherent long-range connectivity with fast, programmable quantum gates.

References

[1] Vandersypen, L. M. K. et al. Interfacing spin qubits in quantum dots and donors—hot, dense, and coherent. npj Quantum Information 3, 34 (2017).

[2] Ademi, Z. et al. Distributing entanglement between distant semiconductor qubit registers using a shared-control shuttling link. Preprint at arXiv:2510.26860.

[3] Beer, M. et al. Conveyor-mode electron shuttling through a T-junction in Si/SiGe. Preprint at arXiv:2601.03942.

[4] Matsumoto, Y. et al. Two-qubit logic and teleportation with mobile spin qubits in silicon. Nature 653, 391–397 (2026)

17:30-18:15 (Short Talks)

- Felix Motzoi (University of Cologne, Germany; Forschungzentrum Juelich, Germany)
  Title: Long distance spin shuttling and logical gates enabled by few-parameter velocity optimization
  Abstract:
  Spin qubit shuttling via moving conveyor-mode quantum dots in Si/SiGe offers a promising route to scalable miniaturized quantum computing. Recent modeling of dephasing via valley degrees of freedom and well disorder dictate slow shutting speeds which limit errors to above correction thresholds if not mitigated. We increase the precision of this prediction, showing that unfortunately typical errors for 10 um shuttling at constant speed results in O(1)

error, using fast, automatically differentiable numerics and including improved disorder modeling. Remarkably, we find that these errors can be brought to well below fault-tolerant thresholds using trajectory shaping with very simple parametrization with as few as 4 Fourier components, well within the means for experimental in-situ realization, and without the need for targeting or knowing the location of valley near degeneracies. Moreover, we examine and demonstrate the possibility of significantly outperforming static EDSR-type single-qubit pulsing by taking advantage of the larger spatial mobility to achieve larger Rabi frequencies and reduce the effect of charge noise. Our theoretical results indicate that fidelities are ultimately bottlenecked by spin-valley physics, which can be suppressed through trajectory optimization.

- David Fernandez-Fernandez (University of Augsburg, Germany; Institute of Materials Science of Madrid (ICMM-CSIC), Spain)
  Title: Spin-orbit-enabled realization of arbitrary two-qubit gates on moving spins
  Abstract:
  Shuttling spin qubits across semiconductor quantum dot arrays is emerging as a key primitive for scalable quantum information processing, enabling on-chip inter-node quantum communication and modular architectures. By analyzing the shuttling of two spin qubits towards each other using a conveyor-mode protocol, we show that controlling only two experimentally accessible parameters, the shuttling velocity and the waiting time at minimum interdot separation, is sufficient to synthesize a broad class of entangling gates. Moderate SOI provides direct access to both CPHASE(theta) and SWAP^alpha families, as well as native fermionic-simulation gates, all with fidelities above 99.99%, neglecting decoherence. We further quantify gate accessibility through a Weyl-chamber analysis and demonstrate that strong SOI or engineered helical magnetic fields can unlock nearly complete (~99.98%) coverage of all locally inequivalent 2Q operations, including quantum gates such as the Berkeley gate. This work provides a realistic and scalable route toward single-step 2Q gates on mobile spin qubits, with immediate implications for distributed quantum computing, quantum simulation, and shuttling-assisted error-correcting architectures.

Thursday, June 11

09:00–09:45

- Monica Benito (University of Augsburg, Germany)
  Title: Optimal gauge choice for spin-photon coupling effective Hamiltonians
  Abstract:
  Gauge invariance is a fundamental principle of light–matter interaction. Hamiltonians formulated in different gauges—such as the Coulomb or dipole gauge—are related by unitary transformations and therefore yield identical predictions. In practice, the matter sector is described in an infinite-dimensional Hilbert space and must be truncated to obtain tractable effective models, such as few-level systems coupled to quantized electromagnetic fields. In applying this projective procedure, apparent gauge dependence arises. This is exactly the case for a spin system coupled to an electric field via spin-orbit coupling. We introduce a continuous family of gauge-related Hamiltonians and study their projected low-energy descriptions. Rather than viewing gauge dependence as a fundamental ambiguity, we interpret it as a redistribution of higher-order perturbative correction. Within this framework, we identify an optimal gauge that minimizes the impact of uncontrolled higher-order terms introduced by truncation. Our results establish optimal gauge choice as a variational principle for improving the accuracy of effective Hamiltonians, ensuring the most faithful representation of spin-photon coupling physics.

10:15–11:00

- Jun Yoneda (University of Tokyo, Japan)
  Title: Exploring Correlated Noise in Silicon Qubit Devices

11:00–11:45

- Xiao Xue (USTC & Hefei National Laboratory, China)
  Title: Quantum computation with spins in silicon: coherence, integration, and scaling
  Abstract:
  In this talk, I will give an overview on our vision on quantum computing with electron spin qubits, and discuss the progress and challenges in realizing fault-tolerant, fully integrated silicon quantum circuits. I will first present our work on characterizing gate fidelities, including the realization of a high-fidelity two-qubit gate that meets the requirement for implementing quantum error correction. Then I will steer the focus to quantum control of spin qubits using a cryo-CMOS chip, named "Horse Ridge", which is a first step towards solving the wiring issues at the quantum-classical interface. Finally, I will present the realization of the

first two-qubit logic between distant spins in silicon, which is achieved by using an on-chip superconducting resonator.

14:45–15:30

- Tetsuo Kodera (Tokyo Institute of Technology, Japan)
  Title: Fundamental technology research toward the integration of semiconductor spin qubits
  Abstract:
  Tetsuo Kodera1*

  1 School of Engineering, Institute of Science Tokyo, 2-12-1 Ookayama, Meguro-ku, Tokyo, 152-8552 Japan

  Quantum computers have been attracting attention as a revolutionary next-generation computer for a long time. In recent years, there is a high expectation for the development of fault-tolerant universal quantum computers that can solve complex problems at high speed. Spins in semiconductor quantum dots are one of the promising candidates for implementing qubits for the fault-tolerant universal quantum computers because of their long coherence times and compatibility with mature silicon technology. In this talk, I first provide a brief introduction of semiconductor spin qubits, including global research and development trends [1]. Then I discuss semiconductor spin qubit devices we have fabricated so far, as well as our research results in charge detection, spin blockade, spin manipulation, and so on. These results are based on precision measurement techniques, including the ability to read out individual electrons and convert spin state information into the presence or absence of charge. I also explain the development of peripheral technologies for integration of semiconductor spin qubits. There are still many challenges to overcome before a fault-tolerant universal quantum computer is realized. It is important that researchers from various technology layers including materials, devices, circuits, control, and systems combine to promote research and development through collaborations between industry, government, and academia.

  [1] T. Kodera, JSAP Rev., 240101, p.1-11 (2024).

15:30–16:15

- Susan Coppersmith (The University of New South Wales, Australia)
  Title: Decoherence of Majorana qubits by 1/f noise
  Abstract:
  Qubits based on Majorana zero modes (MZMs) in superconductor–semiconductor heterostructures have attracted intense interest due to claims that their topological protection will ensure extremely high qubit fidelities.

However, this talk will show that current experiments realizing these qubits in InAs heterostructures are subject to substantial decoherence resulting from the high-frequency components of 1/f charge noise, which is ubiquitous in the materials surrounding the nanowire. This process excites quasiparticle pairs in the bulk of the topological superconductor that cause qubit decoherence even under otherwise ideal conditions. Increasing nanowire capacitance suppresses this mechanism but exposes the qubits to decoherence from externally-generated quasiparticles. Therefore, achieving high-fidelity MZM qubits using superconductor– semiconductor nanowires will require engineering strategies and compromises very similar to those needed for other solid state qubits.

Reference: A. Alase, M. C. Goffage, M. C. Cassidy, S. N. Coppersmith, preprint arXiv:2506.22394

16:45-17:30 (Short Talks)

- Beatriz Perez Gonzalez (University of Augsburg, Germany)
  Title: Floquet theory for the quantum-to-classical crossover of light-matter models
  Abstract:
  Rabi-type Hamiltonians, which comprise either a time-periodic driving or a quantized electromagnetic field, have become ubiquitous across physics. Despite the well-established physics of both the semi-classical and quantum descriptions, when and how classical Floquet physics emerges from a fully quantum treatment remains the subject of active debate [1] and study [2]. We present a unified framework for the quantum-to-classical map ping, emphasizing the gauge-invariant formulation of the quantum Rabi Hamiltonian. This allows a systematic comparison of quasienergies, spectra, entanglement, and dynamics across high- and low frequency regimes, and clarifies how Floquet frames correspond to gauge choices once photonic Fock states are interpreted as Fourier harmonics. We further assess the suitability of quantum high-frequency expansions and benchmark them against alternative methods for deriving effective Hamiltonians, including Schrieffer-Wolff transformations and projector-based approaches.
  [1] Phys. Rev. Lett. 129, 183603 (2022); Phys. Rev. Research 2, 033033 (2020); [2] B. Perez-Gonzalez et al., Quantum 9, 1633 (2025); Comm. Phys. 7, 419 (2024)
- Jose Jesus (Forschungszentrum Juelich, Germany)
  Title: Analytical blueprint for 99.999% single-qubit gate fidelities via multi-photon error suppression on present hardware
  Abstract:
  To attain high-fidelity single-qubit gates on a quantum processor, precise control of the quantum system is required. Nevertheless, such operations suffer from a

plethora of errors arising from residual couplings to higher levels, resulting in leakage and phase errors that limit gate accuracy and make this task significantly challenging. Here, we demonstrate that single-qubit gate errors on the order of 10^(-5) can be achieved by introducing simple control methods based on multi-derivative pulse shaping, termed R1D and R2D, which correct the leading sources of error and enable gate infidelities below 10^(-5) for a 7ns pi-rotation in a superconducting ladder system. Moreover, we show that for a gate duration below ten nanoseconds, modeling the ladder as a three-level system does not provide an adequate description, because multi-photon transitions involving the third excited state become a major source of error. Based on this formalism, we also obtain analytical expressions for the drive amplitude and drive detuning allowing further error suppression and simplifying the calibration process. These results demonstrate that analytical pulse-shaping techniques can substantially improve single-qubit gate performance.

Friday, June 12

09:00–09:45

- Johannes Majer (University of Science and Technology of China, China)
  Title: Quantum Optics with Spins and Superconducting Circuits
  Abstract:
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  Hybrid quantum systems based on spin-ensembles coupled to superconducting microwave cavities are promising candidates for robust experiments in cavity quantum electrodynamics (QED) and for future technologies employing quantum mechanical effects. In particular the electron spins hosted by nitrogen-vacancy centers in diamond. We used this system to study a broad variety of effects, such as cavity protection effect [1] and hole burning [2] which can extend the coherence time and reduce dephasing. Furthermore, this platform allows to study superradiance and the coupling of spins over macroscopic distances.

  We use a dispersive detection scheme based on cQED to observe the spin relaxation of the negatively charged nitrogen vacancy center in diamond. We observe exceptionally long longitudinal relaxation times T1 of up to 8h [3]. To understand the fundamental mechanism of spin-phonon coupling in this system

we develop a theoretical model and calculate the relaxation time ab-initio. The calculations confirm that the low phononic density of states at the NV− transition frequency enables the spin polarization to survive over macroscopic timescales.

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10:15–11:00

- Xinhao Li (Westlake University, China)
  Title: Coherent multi-qubit operation with electrons on solid neon
  Abstract:
  Solid neon has recently emerged as a pristine material host for electron qubits. Single electron-on-solid-neon (eNe) charge qubits have shown extraordinarily long coherence times and high operation fidelities. In this work, we demonstrate frequency- and time-domain coherent manipulation of multiple electron charge qubits confined in proximity on solid neon. Cross-resonance and bSWAP type of two-qubit operations are implemented. Inter-qubit coupling strength exceeding 60 MHz is also observed. These results highlight the potential to scale up the eNe qubit platform.

11:00–11:25 (SIP Industry Session)

- Kosuke Takiguchi (NTT Corporation, Japan)
  Title: Electronic transport properties of titanium nitride grown by molecular beam epitaxy
  Abstract:
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This study investigates how we can fabricate cleaner and more uniform titanium nitride (TiN) superconducting films using molecular beam epitaxy (MBE), a growth technique that enables atomic-level control. TiN is already widely used in superconducting quantum circuits because of its low microwave loss and high kinetic inductance [1,2], but device performance is limited by defects and disorder in the material.

We demonstrate that carefully optimizing the growth temperature significantly improves the crystal quality of TiN films. In our study, we achieved a residual resistivity ratio of 15.8, substantially higher than that of typical sputtered TiN films [3], indicating strong suppression of defect scattering. Structural characterization further revealed that low-temperature growth introduces nitrogen vacancies, whereas higher-temperature growth suppresses these defects and produces nearly stoichiometric TiN.

Using these high-quality films, we performed transport measurements and obtained a superconducting coherence length of approximately 60 nm, longer than values commonly reported for sputtered films (< 40 nm) [4]. This enhanced superconducting coherence is particularly important for quantum devices because disorder and short coherence lengths can lead to decoherence and excess noise. We also combined our experiments with density functional theory calculations to analyze the electronic structure and Hall effect, identifying signatures of anisotropic electron-phonon scattering.

Our results show that improving the quality of epitaxial growth can significantly enhance the intrinsic superconducting properties of TiN, providing a promising pathway toward higher-performance qubits, resonators, and other superconducting quantum-circuit technologies [5-7].

Refs.

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13:30–14:15

- Johannes Pollanen (Michigan State University, USA)
  Title: Strong coupling of a microwave photon to an electron on helium
  Abstract:
  Electrons bound to the surface of superfluid helium have been proposed for scalable charge and spin-based quantum computing. Electrons in this system exhibit exceptionally high mobility, can be precisely shuttled using CMOS-compatible devices, and are predicted to have long coherence times, making them attractive for use as qubits. One promising route to single electron quantum measurement is via a cavity quantum electrodynamics framework, where a photon stored in a cavity interacts with a quantum two-level system. The cavity amplifies the photon–electron interaction so that quantum information is coherently exchanged between a single photon and the electron. This “strong coupling” regime has been utilized for quantum measurement across a wide variety of systems including superconducting qubits, atoms, and semiconductor quantum dots. However, quantum measurement of a single electron on helium has remained elusive due to lack of strong coupling. Here, we use a circuit quantum electrodynamic device that comprises a quantum dot and a high-impedance superconducting resonator to demonstrate, for the first time, strong coupling between a microwave photon and the quantized motional state of a single electron on helium. We demonstrate high-fidelity single electron transport into the dot, showcasing the deterministic single electron control offered by the defect-free helium surface. Reaching the strong coupling regime marks a turning point for the advancement of electron-on-helium-based qubits. Strong coupling to the electron motional state is vital for developing single electron spin readout protocols via spin-orbit hybridization techniques like those utilized in semiconductor quantum dots.

14:15–15:00

- Jun Wang (RIKEN, Japan)
  Title: Coupling Electrons on Solid Neon to a Superconducting Resonator
  Abstract:

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Floating electrons on the surface of liquid helium [1] or solid neon [2] offer a promising two-dimensional platform for realizing qubits. Recently, it has been found that electrons on solid neon exhibit long coherence times. The experimentally measured coherence time of a charge qubit on solid neon has reached around 0.1 ms [3], while the theoretically expected coherence time for a spin qubit is on the order of 1 s [4].

In this talk, we present the trapping of electrons on the surface of solid neon and their coupling to a superconducting resonator. The resonator is fabricated by patterning a sputtered NbTiN film on a silicon substrate. Floating electrons are coupled to the superconducting resonator via the electric field induced by microwave photons inside the resonator. DC voltages applied to the electrodes are used to tune the electrostatic potential experienced by the trapped electrons.

By measuring the transmission signal of the resonator, we measured the coupling strength between the resonator photons and the charge state of a trapped electron to be $g/2\pi$ = 2.1 MHz. We realize a charge qubit and demonstrate coherent control through Rabi oscillations and Ramsey interference. We also investigate how the qubit relaxation time T1 varies with the electron’s environment, obtaining values of 3 μs and 17.7 μs under different conditions.

In future work, we plan to apply an inhomogeneous magnetic field to couple the spin and charge states to realize a spin qubit [5-7].

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15:30-16:15 (Short Talks)

- Dimitrios Georgiadis (Forschungszentrum Juelich, Germany)
  Title: Analytical flux-tuned iSWAP pulse suppressing leakage channels
  Abstract:
  Achieving fast, high-fidelity qubit gates remains one of the major challenges in quantum computing, and despite recent progress, enhancing the efficiency of superconducting two-qubit gates still presents complications. In this work we investigate optimal control methods in order to improve the fidelity of two qubit gates in a flux tunable architecture based on a tunable coupler. We emphasize the importance of suppression of various leakage channels and we demonstrate simulations with optimal control methods, (DRAG) and (DRAG-like), on the external flux on the tunable coupler, achieving further improved fidelities for an iSWAP gate. Finally, we propose a generalized pulse-shaping approach for the external flux, leading to significant leakage suppression across different circuit parameters.
- Janis Peter (University of Tuebingen, Germany)
  Title: Tunable Dispersive and Dissipative Photon-Pressure Interactions in Superconducting Circuits
  Abstract:
  Photon-pressure (PP) circuits implement longitudinal, optomechanical-like interactions, often between low-frequency (MHz) and microwave (GHz) LC circuit modes, and are discussed for dark matter axion detection, MHz quantum photonics and superconducting qubit readout. While most realizations rely on

dispersive PP, where the MHz mode modulates the resonance frequency of the GHz mode, dissipative PP - arising from modulation of the GHz mode decay rate - offers new phenomena and dynamical regimes but has remained largely unexplored.
Here, we present niobium-based photon-pressure circuits with a flux-tunable combination of dispersive and internal-dissipative interactions [1]. Using photon-pressure-induced transparency, we reveal characteristic Fano-like interference between the two interaction pathways and study the resulting modified dynamical backaction under red-sideband pumping. Furthermore, we find multiphoton coupling rates beyond the usual sqrt(n_c) dependence, explained by contributions from the circuit Kerr nonlinearity and nonlinear dissipation. Finally, we will discuss the impact of the twofold interaction on sideband-cooling and present a strategy to integrate external-dissipative coupling in the next device generation.
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