Workshop Introduction

The International Workshop on Semiconductor Spin and Topological Quantum Devices (SSTQD2026) will be held from the 2nd to the 4th of June 2026 in Beijing, China.

The workshop focuses on semiconductor spin quantum computing and hybrid superconductor–semiconductor systems for topological quantum computing, and addresses key scientific and technological challenges involved in the fields. It will bring together global experts and scholars to promote scientific communications, interactions and collaborations. This workshop is featured by invited talks and poster presentations. We sincerely welcome researchers worldwide to join this high-level scientific workshop.

Organizing Committee

Chair:

Hongqi Xu, BAQIS/Peking University

Members:

Ji-Yin Wang, BAQIS
Xiao-Fei Liu, BAQIS
Xing-Jun Wu, BAQIS
Zhi-Hai Liu, BAQIS
Shili Yan, BAQIS
Yu-Jie Zhang, BAQIS

Location

Address： Palace Garden Hole & Resorts, 13 Fengzhi East Road, Haidian Dostrict, Beijing, 100094, China

Conference Venue: Song Dynasty Hall, 1st floor.

Program

Day 0 / June 1

15:00-20:00	**Registration**

Day 1 / June 2

08:00-08:40	**Registration**
08:40-09:00	**Opening remarks**
09:00-09:30	**Noise Impact on Gate Fidelity and Dephasing in Si** *Seigo Tarucha*, RIKEN, Japan
09:30-10:00	**Majorana zero mode for topological quantum computing** *Jinfeng Jia*, Shanghai Jiao Tong University, China
10:00-10:30	**Ge hole quantum devices with suppressed charge noise** *Ji-Yin Wang*, Beijing Academy of Quantum Information Sciences, China
10:30-11:00	**Coffee break**
11:00-11:30	**Quantum Computation with Spins in Silicon — Coherence, Integration, and Scale** *Xiao Xue*, Hefei National Laboratory, China
11:30-12:00	**Josephson effect with topological degeneracy** *Jian Li*, Westlake University, China
12:00-13:30	**Lunch**
13:30-14:00	**More is different: the beauty of multiband in iron-based superconductors** *Hong Ding*, Shanghai Jiao Tong University, China
14:00-14:30	**Recent Progress on Silicon Quantum Dot Quantum Computing** *Guo-Ping Guo/Baochuan Wang*, University of Science and Technology of China, China
14:30-15:00	**Parity Read-out of a minimal Kitaev chain** *Gorm Steffensen*, Madrid Institute of Materials Sciences, Spain
15:00-15:30	**Enhanced Majorana protection in a quantum dot Kitaev chain device** *Chunxiao Liu*, Shanghai Jiao Tong University, China
15:30-16:00	**Coffee break / Poster session**
16:00-16:30	**Semiconductor spin qubits for optical quantum networking** *Akira Oiwa*, The University of Osaka, Japan

16:30-17:00	**Ultrastrong coupling and coherent dynamics in an InAs-Al gatemon qubit** *Eduardo Lee*, Autonomous University of Madrid, Spain
17:00-17:30	**Coexisting topological hinges and 1D Rashba states in $Bi_{0.97}Sb_{0.03}$ revealed by the Josephson effect** *Chuan Li*, University of Twente, the Netherlands
17:30-18:00	**Robust Majorana Platform Driven by a Meissner-Induced Inhomogeneous Doppler Shift** *Xin Liu*, Shanghai Jiao Tong University, China

Day 2 / June 3

08:30-09:00	**Emergent Topology from Landau Level Mixing in Quantum Hall-Superconductor Nanostructures** *Alfredo Levy Yeyati*, Autonomous University of Madrid, Spain
09:00-09:30	**Probing the dominant noise source of a spin qubit near vanishing decoherence field gradient in ^{28}Si/SiGe** *Dohun Kim*, Seoul National University, South Korea
09:30-10:00	**Tailoring nanoscopic phenomena for optimal spin qubit operation** *Jose Carlos Abadillo-Uriel*, Madrid Institute of Materials Sciences, Spain
10:00-10:30	**Coffee break / Poster session**
10:30-11:00	**Si-based quantum wires and wells for quantum computing** *Jianjun Zhang*, Institute of Physics, CAS, China
11:00-11:30	**Growth and Application of Si-Based Semiconductor Quantum Computing Materials** *Guilei Wang*, Beijing Superstring Academy of Memory Technology, China
11:30-12:00	**In Situ Epitaxy of High-Quality Semiconductor-Superconductor Heterostructure Nanowires and Nanowire Networks** *Dong Pan*, Institute of Semiconductors, CAS, China
12:00-13:30	**Lunch**
13:30-14:00	**Shortcuts to adiabaticity for longitudinal spin-photon interfaces in quantum dots** *Xi Chen*, Madrid Institute of Materials Sciences, Spain
14:00-14:30	**Correlated charge noise in semiconductor quantum dot devices** *Wister Wei Huang*, National University of Singapore, Singapore
14:30-15:00	**Measuring the current-phase relation in Josephson junction using superconducting resonators** *Martin Berke*, Budapest University of Technology and Economics, Hungary

15:00-15:30	**Characterization of low-energy states in Kitaev chains** *Ruben Seoane Souto*, Madrid Institute of Materials Sciences, Spain
15:30-16:00	**Coffee break / Poster session**
16:00-16:30	**The integration of quantum dots toward scalable semiconductor spin qubits** *Xiao-Fei Liu*, Beijing Academy of Quantum Information Sciences, China
16:30-17:00	**Universal Logical Operations and Quantum Error Detection in a Silicon Quantum Processor** *Yu He*, Shenzhen International Quantum Academy, China
17:00-17:30	**Superconducting Quantum Interference Devices based on InSb Nanoflag Josephson Junctions** *Stefan Heun*, Istituto Nanoscienze-CNR, Italy
17:30-18:00	**Poster pitch session***
18:00-20:00	**Poster session****

*In this session, each presenter shall give a 1-minute brief introduction to his/her poster with 1 or 2 slides. Then, we have open discussions in the followed poster session.

**Light food and drinks will be served.

Day 3 / June 4

08:30-09:00	**Experimental exploration of the Fu-Kane scheme for topological quantum computation** *Li Lu*, Institute of Physics, CAS, China
09:00-09:30	**Experiments on Kitaev chains in semiconductor–superconductor hybrids** *Francesco Zatelli*, Delft University of Technology, the Netherlands
09:30-10:00	**Gate- and Microwave-Controlled Josephson Transport in III-V Semiconductor Hybrid Josephson Devices** *Xingjun Wu*, Beijing Academy of Quantum Information Sciences, China
10:00-10:30	**Coffee break**
10:30-11:00	**Quantum entanglement between NV centers and their application** *Ya Wang*, University of Science and Technology of China, China
11:00-11:30	**Hamiltonian estimation in semiconductor spin qubits** *Jeroen Danon*, Norwegian University of Science and Technology, Norway
11:30-12:00	**Superconducting spin qubits** *Ramon Aguado*, Madrid Institute of Materials Sciences, Spain
12:00-12:10	**Closing remarks**
12:10-14:00	**Lunch**
14:00-18:00	**Lab tour & Networking activities**

Invited Talks

Day 1 / June 2 / 09:00-09:30

Noise Impact on Gate Fidelity and Dephasing in Si

Seigo Tarucha
RIKEN Center for Emergent Matter Science and RIKEN Center for Quantum Computing Hirosawa,
Wako, Saitama 351-0198, Japan

Silicon quantum dots provide a promising platform for spin-based quantum computing, enabling high-fidelity qubit operations. Achieving such high fidelities is a key prerequisite for fault-tolerant quantum computation, as it can significantly reduce the qubit overhead required for implementing logical operations.

Recently, we demonstrated single-qubit gate fidelities exceeding 99.99% in isotopically purified 28Si/SiGe devices by calibrating gate-pulse errors and optimizing the microwave-burst time window to minimize inter-qubit crosstalk. Through detailed analysis, we identified charge noise as a dominant factor limiting gate fidelity and qubit dephasing. Furthermore, we observed noise correlations between qubits, which give rise to correlated gate errors.

In this talk, I will discuss the impact of charge noise and magnetic noise as the dominant mechanisms limiting gate fidelity, and address strategies for mitigating phase errors.

Seigo Tarucha received the B. E. and M. S. degrees in applied physics from the University of Tokyo in 1976 and 1978, respectively. He joined NTT in 1978 and received the Ph. D degree in applied physics from the University of Tokyo in 1986. In 1998 he moved to the University of Tokyo as a professor in the Department of Physics and then to the Department of Applied Physics in 2004. In March of 2019 he retired from the University of Tokyo and since then has been fully affiliated to RIKEN Center for Emergent Matter Science (CEMS). He has been running a Quantum Functional System research group in CEMS since 2012 and additionally a research team in Center for Quantum Computing (RQC) since 2021. His current research interests have focused on physics and technology of spin-based quantum computing in semiconductor. He received Japan IBM award in 1998, Kubo Ryogo award, Nishina award in 2002, National medal with purple ribbon in 2004, Leo Esaki Award in 2007, Achievement award of Japan Applied Physics Society in 2018, and Fujiwara Award in 2023.

Day 1 / June 2 / 09:30-10:00

Majorana zero mode for topological quantum computing

Jinfeng Jia
Tsung-Dao Lee Institute, Key Laboratory of Artificial Structures and Quantum Control (Ministry of Education), School of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 200240, China
Department of Physics, Southern University of Science and Technology, Shenzhen 518055, China
jfjia@sjtu.edu.cn

Majorana zero mode (MZM), which obeys the non-Abelian braiding statistics, is the building block of the fault-tolerant quantum computation. MZM is predicted to be hosted in topological superconductors. Currently, most topological superconductors are engineered artificially based on a normal superconductor and the exotic properties of the electronic surface states of a topological insulator. As predicted, MZM in the vortex of topological superconductor appears as a zero energy mode with a cone like spatial distribution. Also, MZM can induce spin selective Andreev reflection (SSAR), a novel magnetic property which can be used to detect the MZMs. In the artificial topological superconductor $Bi_2Te_3/NbSe_2$ hetero-structure, all the three features have been observed for the MZMs inside the vortices and fully supported by theoretical analyses. More importantly, all evidences are self-consistent. Recently, the strong proximity effect was found in SnTe-Pb heterostructure. The superconductivity of SnTe is consistent with a new type of topological superconductors under the protection of lattice symmetries. Multiple MZMs under lattice-symmetry protection are observed in a single vortex of the superconducting SnTe. This system provides a platform to study the coupling of multiple MZMs without the need of real space movement of a vortex.

References:
[1] Mei-Xiao Wang, et al., Science **336**, 52-55 (2012)
[2] J.P. Xu, et al., Phys. Rev. Lett. **112**, 217001 (2014)
[3] J.P. Xu, et al., Phys. Rev. Lett. **114**, 017001 (2015)
[4] H.H. Sun, et al., Phys. Rev. Lett. **116**, 257003 (2016)
[5] H.H. Sun, Jin-Feng Jia, NPJ Quan. Mater. **2**, 34 (2017)
[6] H. Yang, et al., Adv. Mater. **31**, 1905582 (2019)
[7] H. Yang, et al., Phys. Rev. Lett. **125**, 136802 (2020)
[8] T. T. Liu, et al., Nature **633**, 71–76 (2024)

Jinfeng Jia is a chair professor of the school of physics and astronomy, Shang-hai Jiao Tong University/acting vice president of Southern University of Science and Technology. He graduated from Peking University in 1987. He received his Ph.D in condensed matter physics from the same university in 1992. From 1995 to 1996, he worked as a JSPS post-doc at Institute for Materials Research, Tohoku University, Japan. From 1996 to 2001, he worked as an associated professor at Department of Physics, Peking University. During the time, he worked as a visiting scientist in USA for 3 years. In 2001, he received the “100 Talents Project” of Chinese Academy of Sciences (CAS) and became a professor at Institute of Physics, CAS. From 2006 to 2009, he worked as a professor at

Department of Physics, Tsinghua University. In 2009, he became a Cheung Kong Professor at Dept. of Physics, Shanghai Jiaotong University. In 2021, he was elected as an academician of CAS.

He is a condensed matter experimenter. His main research interests include topological superconductors and new quantum materials, quantum phenomenon in low-dimensional nano-structures, thin film growth by molecular beam epitaxy. He authored more than 340 SCI papers, including 7 in Science, 3 in Nature, 4 in Nature Phys., 3 in Nature Materials, 30 in Physical Review Letters, with a citation of more than 25000 times.

Day 1 / June 2 / 10:00-10:30

Ge hole quantum devices with suppressed charge noise

Ji-Yin Wang[1], Ding-Ming Huang[1], Jun-Hang Liu[1], Jian-Jun Zhang[2] and H. Q. Xu[1,3]*
1. Beijing Academy of Quantum Information Sciences, Beijing 100193, China
2. Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing, 100190 China
3. Beijing Key Laboratory of Quantum Devices, Peking University, Beijing 100871, China
*wang_jy@baqis.ac.cn

Ge hole gases have been emerging as a promising platform for pursuing advanced spin qubit processors[1]. This stems from the superior properties of Ge hole gases, including low-disorder, strong spin-orbit interaction, and the ability to hybridize with superconductors. Benefitting from these attributes, complex spin qubit processors[2] have been demonstrated in Ge hole gases. At the current stage, charge noise is a primary bottleneck limiting the performance of advanced quantum devices. In order to fully harness the remarkable capabilities of the system, constructing Ge quantum devices with sufficient low charge noise becomes necessary. In this work, we have introduced band structure engineering into the growth of Ge heterostructures to enchance the charge confinement to the hole gases. Hall devices exhibit an enlarged stable gate voltage ranges in the improved Ge heterostructues. Quantum dot devices are made and the noise amplitude of the devices are characterized by noise power spectrum. A typical 1/f characteristic is observed, confirming the dominance of charge noise in the devices. Our devices demonstrate an exceptionally low charge noise at typical ferqencies—from example, 0.46μeV/√Hz at 1 Hz—the lowest reported value for Ge grown on Si substrates. With reduced charge noise and enchanced energy stability, the engineered Ge heterstructures show great potential in building high-performance quantum devices, including spin qubits with long coherence.

References:
[1] G. Scappucci, et al., Nat. Rev. Mater. **6**, 926-943 (2021).
[2] C. A. Wang, et al., Science **385**, 447-452 (2024).

Ji-Yin Wang is currently hired as an associate research scientist of Semiconductor Quantum Computation Group in Beijing Academy of Quantum Information Sciences (BAQIS). He got his B.S. degree from Jilin University in 2013 and got his PhD degree from Peking University in 2018 (supervised by Prof. Hongqi Xu). From 2018 to 2022, he worked as a postdoctoral fellow in QuTech-Microsoft Joint laboratory led by Prof. Leo P. Kouwenhoven. In July of 2022, he joined BAQIS. So far, he has published more than 30 papers in prestigious journals, including Nature, Nature Communications, Science Advances, Nano Letters, Physical Review B, etc. He was elected as overseas high-level personnel and his project is currently funded by National Natural Science Foundation of China. His current research interests include: (1) spin qubits based on semiconductor quantum dots; (2) topological superconductivity based on semiconductor-superconductor hybrids.

Day 1 / June 2 / 11:00-11:30

Quantum Computation with Spins in Silicon — Coherence, Integration, and Scale

Xiao Xue[1,2]
1. *Hefei National Laboratory, University of Science and Technology of China, Hefei 230088, China*
2. *International Quantum Academy, Shenzhen 518048, China*
Email: xiaoxue@hfnl.cn

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 [1, 2]. 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 [3, 4, 5, 6]. 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 [2, 7]. Finally, I will introduce our recent spin qubit experiments, in particular the realization of the first two-qubit logic between distant spins in silicon, which is achieved by using an on-chip superconducting resonator [8, 9].

Reference:
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[7] X. Xue, et al., Nature **593**, 205–210 (2021).
[8] J. Dijkema, X. Xue (equal contribution), et al., Nature Physics **21**, 168–174 (2025).
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Xiao Xue is a principal investigator in Hefei National Laboratory, University of Science and Technology and Shenzhen International Quantum Academy, leading a research group working on quantum computations with spins in semiconductor quantum dots. He obtained his BSc from University of Science and Technology of China and PhD *cum laude* (highest honor) from Delft University of Technology. Before joining HFNL/IQA, he was a postdoc at QuTech, TU Delft and leading a Dutch National Growth Fund - Quantum Technology 2023 to conduct spin qubit research. He was awarded IEEE Jan Van Vessem Award (2020), Steven Hoogendijk Prize (2022), MIT TECH REVIEW “35 innovators under 35” in China (2024), Boeing Quantum Creators Prize (2024).

Day 1 / June 2 / 11:30-12:00

Josephson effect with topological degeneracy

Jian Li[1*] *and Liang-Liang Wang*[1]
1. School of Science, Westlake University, Hangzhou, China
*lijian@westlake.edu.cn

Topological qubit is defined by a ground state manifold with topological degeneracy. The detection of topological degeneracy, however, remains an open problem up to date. In this talk we will propose a topological Josephson junction to detect the topological degeneracy in generic Majorana platforms. In this Josephson junction the topological degeneracy direct leads to unique features in the current phase relation and allows for a parity readout method via critical current switching. We will also discuss signatures that demonstrate the nonlocality associated with this degeneracy, hence verifying its topological nature.

References:
[1] Liang-liang Wang and Jian Li (in preparation).

Jian Li is a principal investigator at Westlake University in Hangzhou, China. He received his Bachelor's Degree from Northwest University, China, in 2002 and Ph.D. in Physics from the University of Hong Kong in 2008. He worked as a postdoc with Markus Büttiker in University of Geneva and then with B. Andrei Bernevig in Princeton University, before joining Westlake University as a faculty member in 2017.

Day 1 / June 2 / 13:30-14:00

More is different: the beauty of multiband in iron-based superconductors

Hong Ding
Tsung-Dao Lee Institute, Shanghai Jiao Tong University, China
dingh@sjtu.edu.cn

In a paradigm-shifting article “More is different” in 1972, Phil Anderson pointed out that new properties can emerge from a many-body system, which cannot be derived from the constituent particles. In this talk I will illustrate that even two or three can be regarded as “more” in the world of superconductors. I will highlight the unnoticed beauty of multiband of iron-based superconductors, including 1. Emergence of topological band which coexists with superconductivity, leading to the discovery of Majorana zero mode; 2. Interplay of multicomponent superconductivity, leading to the discoveries of exotic paring with time-reversal symmetry breaking and fractional vortex; 3. Contribution of Hund coupling towards pairing in this unique class of superconductors.

Hong Ding, T.D. Lee Chair Professor of Tsung-Dao Lee Institute at Shanghai Jiao Tong University, Academician of Chinese Academy of Sciences. He has made several scientific discoveries, including discovery of pseudogap in cuprate superconductors, observation of s-wave superconducting gap in iron-based superconductors, discovery of Weyl fermions in solids, and discovery of Majorana zero modes in iron-based superconductors. His achievements have been selected as Top Ten Scientific Advancements in China and/or Top Ten News of Science and technology in China of the years 2015, 2017, and 2018. He has published more than 300 papers with total citations over 20000. He received Sloan Research Fellowship Award, European Advanced Materials Award, Outstanding Science and Technology Achievement Prize of Chinese Academy of Sciences, New Cornerstone Investigator, TWAS Award in Physics, Astronomy & Space Sciences, Future Science Prize, and Ho Leung Ho Lee Prize for Scientific and Technological Progress.

Day 1 / June 2 / 14:00-14:30

Recent Progress on Silicon Quantum Dot Quantum Computing

Guo-Ping Guo/ Baochuan Wang

Silicon-based semiconductor quantum dots have emerged as a leading platform for scalable quantum computation, leveraging compatibility with mature CMOS fabrication technologies. This talk reviews recent important progress across several critical fronts, including: advances in demonstrations of single- and two-qubit gate fidelities surpassing the fault-tolerance quantum computing threshold in both electron and hole spin qubit in Silicon and Germanium; successful implementation of multi-qubit entanglement and execution of small-scale quantum algorithms on multi-qubit arrays in Silicon; innovative approaches to long-range qubit coupling via high-impedance superconducting microwave resonators facilitating non-local interactions essential for modular architectures; and the development of spin shuttling techniques for coherent transport of spins across large quantum dot arrays, enabling dynamic qubit connectivity. We highlight our group's contributions in fast and high-fidelity control, multi-qubit integration, and the realization of cavity-mediated coupling of spin qubits in silicon quantum dot devices. These collective advances underscore a clear pathway toward fault-tolerant, large-scale quantum processors based on silicon spin qubits.

Guoping Guo, is currently a Professor and Principal Investigator of the silicon-based semiconductor quantum dot quantum computing group at University of Science and Technology of China. He serves as Chief Scientist of the Innovation Program for Quantum Science and Technology and is a recipient of the National Science Fund for distinguished Young Scholars award from the National Natural Science Foundation of China. Professor Guo has long been engaged in solid-state quantum computing research and has achieved a series of innovative results in qubit encoding, control, and scalable architectures for semiconductor-based systems. In recent years, his group has made notable breakthroughs in silicon-based quantum computing, including fast and high-fidelity qubit manipulation, as well as the coupling of silicon spin qubits via superconducting resonators.

Baochuan Wang, is currently a Junior Research Fellow at Hefei National Laboratory. He received his Ph.D. from University of Science and Technology of China in 2017, after which he joined Guoping Guo's group as a Postdoctoral Research Fellow and later served as an Associate Research Fellow. His current research focuses on high-fidelity spin qubit control and the scaling of spin qubits in silicon quantum dots.

Day 1 / June 2 / 14:30-15:00

Parity Read-out of a minimal Kitaev chain

Gorm Steffensen

Minimal Kitaev chains, based on quantum dots coupled by superconductors, is a promising platform for realizing and manipulating semi-protected Majorana fermions – known as Poor man's Majorana's (PMM). These PMM's encodes the fermionic parity that serves as the logical state in a parity qubit. In this talk, I will present the theory underlying quantum capacitance-based read-out of PMM fermionic parity, and its correlation to independent local charge measurements of one quantum dot. As the Kitaev chain is now floating, compared to electrically grounded, new protocols are required to measure and tune the chain towards the PMM sweet-spot. To tackle this, I will cover various methods to determine the charge neutrality and state degeneracy required of a PMM sweet-spot. These results serve as stepping stone towards full parity qubits and topological operations.

I am an independent post-doc at the Niels Bohr institute primarily engaged in the theory of transport and non-equilibrium effects in semiconducting-superconducting hybrid devices. Subgap states of all shapes and sizes are dear to my heart.

Day 1 / June 2 / 15:00-15:30

Enhanced Majorana protection in a quantum dot Kitaev chain device

Chun-Xiao Liu [1,2*]
1. Tsung-Dao Lee Institute, Shanghai Jiao Tong University, Shanghai 201210, China
2. School of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 200240, China
*Chunxiaoliu62@sjtu.edu.cn

Topological superconductivity can host Majorana zero modes at the defects or boundaries. These exotic modes are Ising anyons that obey the non-Abelian exchange statistics and can be used to implement error-resilient topological quantum computing. In recent years, quantum-dot-superconductor array has emerged as a new and promising platform for realizing topological Kitaev chains and Majorana zero modes [1, 2]. In this talk, I will talk about the theoretical proposals and experimental progresses of realizing the Kitaev chain in this new platform. In particular, I will discuss our recent efforts in scaling up the Kitaev chain, the observation of enhanced Majorana protection, and the potential implication of protected Majorana qubit [3-6].

References:
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[5] S. L. D. ten Haaf, Y. Zhang, et. al. Nature **641**, 890 (2025)
[6] H. Pan, S. Das Sarma, and C.-X. Liu Phys. Rev. B **111**, 075416 (2025)

Chun-Xiao Liu obtained his PhD degree in condensed matter theory at University of Maryland, College Park in 2018, under the joint supervision of Prof. Jay D. Sau and Prof. Sankar Das Sarma. He then moved to QuTech, Delft University of Technology, the Netherlands to work as a postdoc in Prof. Michael Wimmer and Prof. Anton Akhmerov's group, before being promoted as a permanent researcher in 2023. In 2025, he joined Tsung-Dao Lee Institute, Shanghai Jiao Tong University as a tenure-track associate professor. His research interest covers topological phases of matter, Majorana zero mode, mesoscopic quantum transport, quantum device physics, quantum dynamics, and topological quantum computing.

Day 1 / June 2 / 16:00-16:30

Semiconductor spin qubits for optical quantum networking

Akira Oiwa[1,2,3] *

1. SANKEN, The University of Osaka, 8-1 Mihogaoka, Ibaraki, Osaka 567-0047, Japan
2. Center for Quantum Information and Quantum Biology, The University of Osaka,1-2 Machikaneyama, Toyonaka, Osaka, 560-0043, Japan
3. Spintronics Research Network Division, Institute for Open and Transdisciplinary Research Initiatives, The University of Osaka, 2-1 Yamadaoka, Suita, Osaka 565-0871, Japan
*oiwa@sanken.osaka-u.ac.jp

Semiconductor spin qubits provide a promising platform for fault-tolerant quantum computers (FTQCs) because of relatively long spin coherence time in solid state devices and high-electrical tuneability of the quantum states [1]. In addition, semiconductors have great potential for applications in quantum communications owing to their abilities in optical devices. Especially in quantum repeater applications, the semiconductor spin qubits provide ways to connect quantum computers via optical fiber and construct global quantum networks, contributing to realize secure quantum communications and distributed quantum computing [2,3].

In this talk, we present the basic concept of the quantum state conversion from single photon polarization states to single electron spin states in gate-defined quantum dots (QDs) and its demonstration [4,5]. We also show that the enhancement of the conversion efficiency from a single photon to a single spin in a quantum dot using photonic nanostructure and an optical cavity [6,7]. In addition, we discuss recent achievements and perspectives of quantum repeaters based on semiconductor spin qubits.

References

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[6] R. Fukai et al., Appl. Phys. Express **14**, 125001 (2021)
[7] S. Ji et al., Jpn. J. Appl. Phys. **62**, SC1018 (2023).

Prof. **Oiwa** got PhD in 1999 from The University of Tokyo. Then he joined Kanagawa Academy of Science and Technology as a researcher. During his time as a graduate student and postdoctoral researcher periods, he worked on diluted magnetic semiconductors in the field of spintronics. He started my research on semiconductor quantum dots when he became a lecturer at the University of Tokyo. Since then, he have conducted various studies on quantum state conversion between photons and spins, elucidation of spin-orbit interaction in QDs and superconducting junctions of quantum dots. After becoming professor at SANKEN, the University of Osaka, his research topics has been focusing on the application of semiconductor qubits to quantum networks.

Day 1 / June 2 / 16:30-17:00

Ultrastrong coupling and coherent dynamics in an InAs-Al gatemon qubit

I. Casal Iglesias[1, 2], F. J. Matute-Cañadas[2, 3], G. O. Steffensen[4, 5], A. Ibabe[1, 4, 5], L. Splitthoff[6], T. Kanne[7], J. Nygård[7], V. Rollano[8], D. Granados[9], A. Gomez[8], R. Aguado[4, 5], A. Levy Yeyati[2, 3, 5], E. J. H. Lee[1, 2, 5]

1. Departamento de Física de la Materia Condensada, Universidad Autónoma de Madrid, 28049 Madrid, Spain
2. Condensed Matter Physics Center (IFIMAC) and Instituto Nicolás Cabrera (INC), Universidad Autónoma de Madrid, 28049 Madrid, Spain
3. Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, 28049 Madrid, Spain
4. Instituto de Ciencia de Materiales de Madrid (ICMM), Consejo Superior de Investigaciones Científicas (CSIC), Sor Juana Inés de la Cruz 3, 28049 Madrid, Spain
5. Laboratorio de Transporte Cuántico, Unidad Asociada UAM/ICMM-CSIC, Madrid, Spain
6. QuTech and Kavli Institute of Nanoscience, Delft University of Technology, 2600 GA Delft, Netherlands
7. Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen, Denmark
8. Centro de Astrobiología (CSIC - INTA), Torrejón de Ardoz, 28850 Madrid, Spain
9. IMDEA Nanociencia, Cantoblanco, 28049 Madrid, Spain
*eduardo.lee@uam.es

We implement a gate-tunable transmon (gatemon) qubit [1,2] based on a hybrid InAs-Al nanowire Josephson junction and identify distinct features in its microwave spectra that provide clear evidence of ultrastrong light-matter hybridization with a superconducting resonator. Our measurements reveal an avoided crossing that cannot be captured by the Jaynes-Cummings model, as well as photon-number-dependent transitions whose energies deviate markedly from the Jaynes-Cummings ladder expected in the strong coupling regime. Beyond demonstrating USC, we achieve time-resolved coherent control of the qubit and measure coherence times comparable to gatemons operating outside the ultrastrong coupling regime [3]. These results establish that hybrid superconductor-semiconductor qubits can retain coherent control in ultrastrong coupling and provide a platform for exploring quantum dynamics in this regime.

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Eduardo J. H. Lee is Professor and Group Leader at the Condensed Matter Physics Center (IFIMAC) of the Autonomous University of Madrid, Spain. He established his independent research group and a quantum transport laboratory upon joining IFIMAC, where his work focuses on devices based on hybrid superconducting nanostructures.

Day 1 / June 2 / 17:00-17:30

Coexisting topological hinges and 1D Rashba states in $Bi_{0.97}Sb_{0.03}$ revealed by the Josephson effect

Biplab Bhattacharyya[1], *Stijn R. de Wit*[1], *Zhen Wu*[1], *Yingkai Huang*[2], *Mark S. Golden*[2], *Alexander Brinkman*[1], *Chuan Li*[1]*
1 1MESA+ Institute, University of Twente, Enschede, the Netherlands
2Van der Waals–Zeeman Institute, IoP, University of Amsterdam, Amsterdam, the Netherlands

Second-order topological insulating (SOTI) states in three-dimensional materials are helical one-dimensional hinge states. Inducing superconductivity in these states leads to gapless bound states, characterized by the 4π-periodic current-phase relation. Here, we provide evidence of the topologically

protected hinge states in Dirac semimetal $Bi_{0.97}Sb_{0.03}$ nanoflakes by an unconventional interference pattern in a magnetic field, and the 4π-periodic supercurrent carried by these states via the suppressed first and third Shapiro steps. Tight-binding simulations confirm the presence of multiple hinge modes, supporting our interpretation of $Bi_{0.97}Sb_{0.03}$ as a prototypical designable SOTI platform. Quantum confinement effect is identified by a quasi-one-dimensional bulk transport, and the confined Rashba states are responsible for the broadened hinge states.

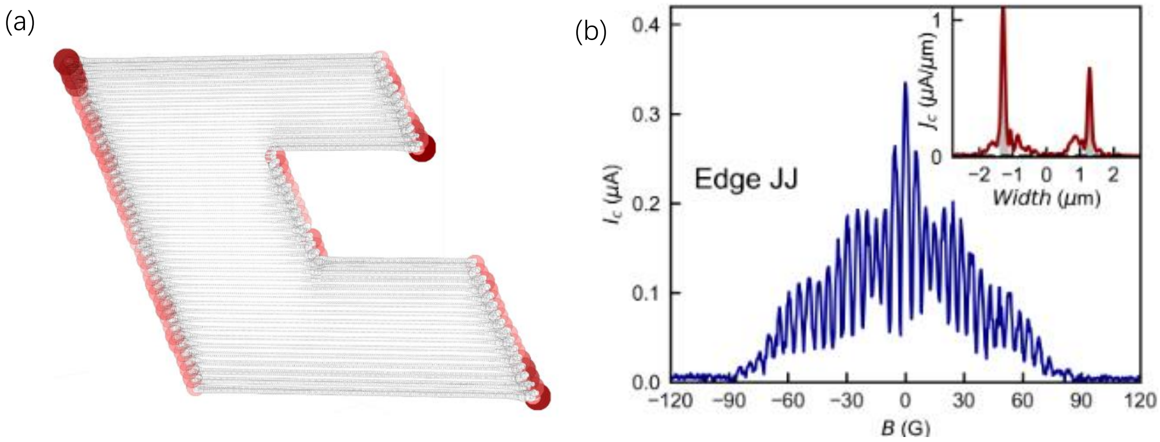

Figure 1: Multi-channel in $Bi_{0.97}Sb_{0.03}$. (a) tight-binding calculation for a $Bi_{0.97}Sb_{0.03}$ infinite slab with a discontinuous side facet. An extra mode is apparent. (b) critical current as a function of magnetic field I_c (B). Insert: converted current density distribution J_c (x).

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B. Bhattacharyya, et al. arXiv:2505.02995v1

Chuan Li is an associate professor in physics department at the University of Twente. She completed her Ph.D. and master study in fundamental physics at the univsertié Paris 11 (now University Paris-Saclay). She received her Ph.D. degree in 2014 for her dissertation on "Superconducting proximity effect in graphene and Bi nanowire-based Josephson junctions." Since 2015, she joined the ICE (interfaces and correlated electrons) group at the University of Twente in The Netherlands, and became an assistant professor in 2017. She is mainly focusing on the quantum transport in topological material-based superconducting devices in both low frequency and radio-frequency regions.

Day 1 / June 2 / 17:30-18:00

Robust Majorana Platform Driven by a Meissner-Induced Inhomogeneous Doppler Shift

Xin Liu[1*], *Xiao-Hong Pan*[2], *and Fu-Chun Zhang*[3]

1. Tsung-Dao Lee Institute and School of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 201210, China

2. College of Physics & Optoelectronic Engineering, Department of Physics, Jinan University, Guangzhou 510632, China.

3. Kavli Institute for Theoretical Sciences, University of Chinese Academy of Sciences, Beijing 100190, China

*phyliuxin@sjtu.edu.cn

Realizing robust Majorana zero modes (MZMs) in hybrid structures requires balancing superconducting proximity against interfacial renormalization. Stronger SC/TI coupling can harden the induced superconducting gap, but it also enhances interface renormalization, limiting the simultaneous improvement of superconducting proximity and the topological gap while increasing the complexity of interface engineering. Here, we propose and validate a general mechanism based on a Meissner-induced inhomogeneous Doppler response that stabilizes the topological phase transition across a broad coupling range, including the strong-coupling regime. In a partially superconducting-covered topological-insulator nanowire, this inhomogeneity produces a spatial separation between two roles: the SC/TI interface remains the strongly proximitized hard-gap sector, while the gate-tunable bottom surface becomes the transition-driving sector where a flux-driven topological phase transition occurs. Using a multiscale framework that combines supercurrent simulations, self-consistent Schrödinger-Poisson electrostatics, and large-scale tight-binding calculations, we show that this mechanism survives realistic device conditions: the transition location is only weakly dependent on chemical potential, the reopened topological gap is optimized near the bottom-surface Dirac point, and the resulting Majorana regime remains stable against strong disorder in the tested range. Our work establishes a practical design principle and a realistic route toward robust topological superconductivity in SC/TI hybrids.

[1] Xiao-Hong Pan, Si-Qi Yu, Li Chen, Fu-Chun Zhang, Xin Liu, arXiv:2509.24686

Prof. **Xin Liu** received his B.S. and M.S. degrees from Nankai University and Chern Institute of Mathematics, Tianjin. He received his Ph.D. from Texas A&M University in 2012. After graduation, he worked as a postdoctoral researcher at Pennsylvania State University from 2012 to 2014 and at the Condensed Matter Theory Center at the University of Maryland from 2014 to 2015. He joined Huazhong University of Science and Technology in 2015 and Tsung-Dao Lee Institute, Shanghai Jiao Tong University in 2024.

Day 2 / June 3 / 08:30-09:00

Emergent Topology from Landau Level Mixing in Quantum Hall-Superconductor Nanostructures

Y. Baba, P. Burset and A. Levy Yeyati

We reveal the emergence of unconventional topological phases in quantum Hall–superconductor hybrid structures driven by Landau-level mixing and spin–orbit coupling. For a narrow superconducting stripe atop a two-dimensional electron gas, hybridization of chiral Andreev edge states yields a rich phase diagram, including the unexpected realization of the long-sought p-wave superconducting state at even filling factors, thus allowing its detection at lower fields. These phases feature quantized nonlocal conductance from electron cotunneling at filling factor $\nu = 1$, coexisting with quantized crossed Andreev reflection at $\nu = 2$. Notably, this results in the excitation of a neutral mode with remarkable thermoelectric response, offering new means to probe correlated transport. Numerical simulations and effective modeling reveal how spin–orbit coupling and geometry control these transitions, enabling realistic routes to engineer topology in proximized quantum Hall devices.

Alfredo Levy Yeyati is Full Professor at the Universidad Autónoma de Madrid. His research focuses on theoretical condensed matter physics, with special emphasis on quantum transport phenomena in mesoscopic and nanoscale systems, superconductivity, electronic correlations and topological effects.

Day 2 / June 3 / 09:00-09:30

Probing the dominant noise source of a spin qubit near vanishing decoherence field gradient in ^{28}Si/SiGe

Shinwoo Lee[1]*, Hanseo Son*[1]*, Jaemin Park*[1]*, Hyeongyu Jang*[1]*, Jongin Yun*[1]*, Jun Yoneda*[2]*,*
Lucas E. A. Stehouwer[3]*, Davide Degli Esposti*[3]*, Giordano Scappucci*[3]*, and Dohun Kim*[1*]
1. Department of Physics and Astronomy, and Institute of Applied Physics, Seoul National University, Seoul 08826, Korea
2. Department of Advanced Materials Science, Graduate School of Frontier Sciences, The University of Tokyo, Kashiwa, Chiba 277-8561, Japan
3. QuTech and Kavli Institute of Nanoscience, Delft University of Technology, PO Box 5046, 2600 GA Delft, The Netherlands
*Corresponding author: dohunkim@snu.ac.kr

Silicon spin qubits have become one of the most promising platforms for scalable quantum computing due to their long coherence times and compatibility with mature nanofabrication technologies. Although micromagnet-based spin resonance is widely used for electrical control of silicon spin qubits, the significant reduction in coherence caused by the decoherence field gradient remains a major challenge. We present an exceptional case in a ^{28}Si/SiGe quantum dot device (800 ppm of ^{29}Si) where the qubit is situated near a vanishing decoherence field gradient, demonstrating a long coherence time ($T^{2*} > 60\ \mu s$, TDD > 5 ms). Using a newly developed correlation noise spectroscopy technique, we show that the qubit exhibits negligible noise correlations with its nearest-neighbor qubit but significant correlations with the nearby charge sensor signal. We discuss local charge fluctuators as the dominant noise sources, even for this exceptional qubit, suggesting that isotopic purification of ^{29}Si down to 800 ppm, in the absence of transduced noise, can enable even higher nuclear noise-limited coherence times.

Prof. **Dohun Kim** did his Ph.D in University of Maryland on quantum transport of topological materials. During his post-doc study in University of Wisconsin, he made the major contribution in inventing silicon spin-charge hybrid qubit in Si/SiGe. Starting from 2016, he leads a group in Seoul National University, South Korea on quantum computing experiments based on spin qubits in silicon.

Day 2 / June 3 / 09:30-10:00

Tailoring nanoscopic phenomena for optimal spin qubit operation

José C. Abadillo-Uriel[1,2]
1. Instituto de Ciencia de Materiales de Madrid, CSIC, Madrid, Spain
2. Quantum Advanced Research Center, QuARC-CSIC, Madrid, Spain
*jc.abadillo.uriel@csic.es

Hole spin qubits in silicon and germanium have reached a stage where the key question is no longer whether they can be controlled, but how to optimize control in increasingly complex device architectures [1-4]. Their strong spin-orbit interaction enables all-electrical driving and spin-photon coupling, but also makes them highly sensitive to details often treated as secondary in simplified models: the full gate-defined electrostatics, non-separable confinement, strain gradients, and interdot tunneling. In this talk I will argue that these nanoscopic details are not mere perturbations; they often set the relevant low-energy physics and, once understood, become resources for qubit design. I will show that spin-orbit mechanisms beyond the standard picture can emerge directly from realistic device structure. In gate-defined hole dots, inhomogeneous and non-separable electric fields generate additional spin-orbit terms and g-matrix modulations that can dominate electrical spin driving [5]. Strain inhomogeneities likewise induce linear Rashba-like interactions and g-factor modulations that explain fast Rabi oscillations, including operation under in-plane magnetic fields where homogeneous Rashba pictures fail [6]. We have also found that the same ingredients shape spin-photon interactions [4, 7]. In sparse arrays, where tunneling is itself part of the control toolbox, even-in-momentum spin-orbit terms generate spin-dependent magneto-tunneling corrections to the effective g-tensor [8], enabling sweet-spot operation. The same physics extends to hybrid Ge superconductor-semiconductor devices [9-11], where it reshapes the induced superconducting correlations and magnetic-field response. Overall, I will argue that optimal qubit operation requires going beyond minimal models and embracing the nanoscopic complexity of real devices.

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José Carlos Abadillo-Uriel did his PhD on dopant-based quantum computation at CSIC. He then started a postdoctoral in 2018 stay at the University of Wisconsin-Madison in the Silicon Qubit Theory Group where he worked on quantum-dot qubits, Wigner molecules, and cQED. He then moved in 2021 to CEA Grenoble to the L-Sim group where he worked on the theory and simulation of hole spin qubits and spin-photon coupling. Now, he has gotten back to CSIC as a young PI under the Ramón y Cajal fellowship, where he studies semiconductor-based spin qubits, photon-mediated interactions, and hybrid superconductor-semiconductor devices.

Day 2 / June 3 / 10:30-11:00

Si-based quantum wires and wells for quantum computing

Jian-Jun Zhang
Institute of Physics, Chinese Academy of Sciences, Beijing 100190, P. R. China
*jjzhang@iphy.ac.cn

Silicon based SiGe materials have emerged as pivotal platforms for advancing semiconductor quantum computing, leveraging their compatibility with mature CMOS processes and unique quantum properties. Unlike III-V semiconductor systems plagued by short decoherence times due to nuclear spin hyperfine interactions, isotopically purified Si and Ge offer near-zero nuclear spin environments, enabling significantly extended qubit coherence times. In this talk, I will present our research on the molecular beam epitaxy (MBE) growth of Si-based Ge quantum wires and wells for spin qubit applications. On trench-patterned Si (001) substrates, we have achieved controlled growth of Ge quantum wires with a mobility exceeding 2×10^4 $cm^2\cdot V^{-1}\cdot s^{-1}$. For quantum wells, we have obtained hole and electron mobilities of 2.4×10^5 $cm^2\cdot V^{-1}\cdot s^{-1}$ and 5.2×10^5 $cm^2\cdot V^{-1}\cdot s^{-1}$, respectively. Collaboratively, we have demonstrated the first Ge hole qubit and achieved ultrafast operation of hole spin qubits in Ge quantum wires.

Jianjun Zhang is a Professor at the Institute of Physics (IOP) of the Chinese Academy of Sciences (CAS) and serves as the director of the CAS Key Laboratory of Nanoscale Physics and Devices. He earned his PhD from Johannes Kepler University Linz in 2010. Following his doctoral studies, he conducted research at the Leibniz Institute for Solid State and Materials Research in Dresden and the Centre for Quantum Computation and Communication Technology in UNSW Sydney before joining IOP in 2014. His group focuses on silicon-based low-dimensional materials for photonics and quantum devices.

Day 2 / June 3 / 11:00-11:30

Growth and Application of Si-Based Semiconductor Quantum Computing Materials

GuiLei Wang[1,2]
1 Beijing Superstring Academy of Memory Technology, Beijing 100176, China
2 Hefei National Laboratory, Hefei, Anhui 230088, China
guilei.wang@bjsamt.org.cn

Semiconductor integrated circuits (ICs) have been miniaturized for decades following "Moore's Law," with increasingly high integrated densities of transistors on a single chip while the critical size (CD) of transistor gets smaller and smaller. There are great challenges with shrinkage in size. Si-based quantum computing is expected to become one of the key technologies for the development of current semiconductor ICs in the future. However, the quality of traditional Si semiconductor materials needs to be further developed, purified and improved to meet the needs of quantum computing applications. In this topic, we are focusing on the high mobility of silicon semiconductor materials (SiGe and Ge) growth by chemical vapor deposition (CVD), process integrated in quantum computing chips in complementary metal-oxide-semiconductor (CMOS) platform. We present the researches about the process of SiGe full relaxation substrate, the growth of high Ge content strained SiGe, the growth (CVD) and application of high purity 28Si material. These Si-based materials have been extensively characterized to satisfy the demands for semiconductor quantum devices.

Dr. **Guilei Wang** earned his PhD degree from the University of Chinese Academy of Sciences (UCAS) in 2016. He served as a Professor at the Institute of Microelectronics of the Chinese Academy of Sciences (IMECAS) until 2021. In October 2021, he joined the Beijing Superstring Academy of Memory Technology (SAMT), where he currently holds the positions of Full Professor and Vice President. His research interests focus on Group IV materials growth, devices fabrication, and process integration for the integrated circuit (IC) industry and Si semiconductor quantum computing. To date, he has published over 180 research papers in renowned international journals and conferences. He has authored and co-authored more than 173 Chinese invention patents, as well as 20 patents in the United States and Europe. Additionally, he has authored 1 book and 1 chapter on SiGe epitaxy.

Day 2 / June 3 / 11:30-12:00

In Situ Epitaxy of High-Quality Semiconductor-Superconductor Heterostructure Nanowires and Nanowire Networks for Quantum Devices

Dong Pan
State Key Laboratory of Semiconductor Physics and Chip Technologies, Institute of Semiconductors,
Chinese Academy of Sciences, P.O. Box 912, Beijing 100083, China
*E-mail: pandong@semi.ac.cn

Over the past decade, significant progress has been made in topological quantum computing research based on semiconductor-superconductor heterostructure nanowires [1-7]. However, achieving atomic-scale engineering of the semiconductor-superconductor heterointerface to fabricate quantum materials that can robustly host Majorana zero modes remains a critical challenge for III-V semiconductor-superconductor-based topological quantum computing. To address this challenge, in this talk I will present our recent advances in the molecular-beam epitaxy growth of high-quality one-dimensional InAs, InSb, and ternary InAsSb nanowires [8-11]. Furthermore, I will report our breakthrough in low-temperature in situ epitaxy of superconducting Al on the sidewalls of phase-pure ultrathin InAs nanowires [12,13]. Finally, I will introduce our latest progress in planar selective area epitaxy of semiconductor-superconductor heterostructure nanowire networks [14].

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Dong Pan received his Ph.D. degree in condensed matter physics from the Institute of Semiconductors, Chinese Academy of Sciences (ISCAS), China, in 2014. He is currently a Professor at the State Key Laboratory of Semiconductor Physics and Chip Technologies, ISCAS. Over the past decade, he has been consistently focusing on the controllable molecular-beam epitaxy growth of semiconductor-superconductor heterostructure nanowires and nanowire networks for topological quantum computing. He is the author of more than 130 SCI-indexed articles and holds 10 original patents. He is an outstanding member of the Youth Innovation Promotion Association, Chinese Academy of Sciences.

Day 2 / June 3 / 13:30-14:00

Shortcuts to adiabaticity for longitudinal spin-photon interfaces in quantum dots

*Mo Zhou[1,2], Yue Ban[2], Gloria Platero[2] and Xi Chen[2]**
1. Department of Physics, Shanghai University, Shanghai 200444, China
2. Instituto de Ciencia de Materiales de Madrid ICMM-CSIC, Madrid 28049, Spain
*xi.chen@csic.es

Longitudinal spin-photon coupling in semiconductor quantum dots provides a promising route toward fast and flexible quantum control [1]. In particular, hole-spin qubits in Si and Ge quantum dots exhibit strong electrically tunable spin–orbit interaction and anisotropic g-tensors, enabling the spin-photon interaction to be tuned from transverse to longitudinal by adjusting the magnetic-field orientation. In the longitudinal regime, the resonator field modulates the qubit energy splitting without inducing spin flips, which naturally suppresses unwanted excitation exchange and enables quantum nondemolition operations, fast entangling gates, and reduced backaction [2–4]. Here we develop a unified framework based on shortcuts to adiabaticity (STA) [5] to engineer time-dependent longitudinal spin-photon interfaces for semiconductor spin qubits [6–8]. Combining inverse engineering with an exact polaron-like unitary transformation, we derive analytical control protocols that directly map target operations onto tunable longitudinal couplings. The central idea is to design auxiliary trajectories that enforce closed-loop resonator displacements, so that the cavity returns to vacuum while the qubits acquire the desired phases. For a single qubit, this enables fast high-fidelity phase gates without residual qubit–photon entanglement. For two qubits, it yields an effective controllable ZZ interaction and fast entangling gates such as the controlled-Z gate, without the resonance-time restrictions of conventional modulated-pulse schemes. The method also extends naturally to multi-qubit systems, generating programmable Ising-type interactions and multipartite entangled states, including GHZ states. We also analyze realistic imperfections, including low-frequency dephasing, cavity dissipation, and residual transverse coupling. Fast STA protocols suppress dephasing errors, while smooth pulse shaping mitigates photon-loss-induced residual cavity displacement. These results establish STA-engineered longitudinal coupling as a scalable and versatile paradigm for quantum control in solid-state platforms.

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Xi Chen is a Senior Scientist at ICMM-CSIC and a pioneer of shortcuts to adiabaticity, whose research spans quantum optics, quantum control, and quantum computing.

Day 2 / June 3 / 14:00-14:30

Correlated charge noise in semiconductor quantum dot devices

Petar Tomić[1], Patrick Bütler[1], Yuze Wu[1], Bart Raes[2], Clement Godfrin[2], Stefan Kubicek[2], Julien Jussot[2], Yann Canvel[2], Yannick Hermans[2], Yosuke Shimura[2], Roger Loo[2], Sofie Beyne[2], Gulzat Jaliel[2], Thomas Van Caekenberghe[2,3], Vukan Levajac[2], Danny Wan[2], Kristiaan De Greve[2,4], Wister Wei Huang[1,5], Klaus Ensslin[1], and Thomas Ihn[1]
[1] *Laboratory for Solid State Physics, ETH Zürich, CH-8093 Zürich, Switzerland*
[2] *IMEC, 3001 Leuven, Belgium*
[3] *Department of Electrical Engineering (ESAT), KU Leuven, Leuven, Belgium*
[4] *Proximus Chair in Quantum Science and Technology, Department of Electrical Engineering (ESAT-MNS), KU Leuven, B-3001 Leuven, Belgium*
[5] *National University of Singapore, 119260 Singapore*

Charge noise remains one of the central limitations for scalable semiconductor spin qubits, affecting device stability, qubit dephasing, and multi-qubit gate performance. While substantial progress has been made in improving coherence and control in silicon quantum dots [1–5], understanding the spatial and temporal correlations of charge noise across extended device arrays is increasingly important for scalable architectures. In this work, we investigate correlated noise in semiconductor quantum dot devices and use device-to-device reproducibility as a basis for systematic noise studies across multiple gates, dots, and device locations.

By measuring fluctuations in charge stability diagrams, gate-based sensor responses, and qubit frequency shifts, we extract local and nonlocal noise components and analyze correlations across different electrostatic control channels. These measurements allow us to distinguish noise sources that are local to individual gates or interfaces from noise mechanisms that produce correlated shifts across multiple quantum dots. Such correlated fluctuations are particularly relevant for larger quantum dot arrays, where common-mode noise, long-range electrostatic coupling, and shared dielectric or interface environments can lead to collective instability beyond what is inferred from single-dot measurements [6–8].

Our results highlight spatially resolved noise spectroscopy as a diagnostic tool for semiconductor quantum devices. In particular, correlation measurements can reveal whether dominant charge fluctuations act in a differential or common-mode manner, which directly determines their impact on different qubit encodings. For singlet–triplet qubits, common-mode fluctuations can be partially rejected because the encoded qubit is primarily sensitive to energy differences between two dots [9,10]. These findings suggest that understanding noise correlations, rather than only reducing average noise levels in individual devices, is essential for optimizing qubit encodings and developing reliable large-scale semiconductor spin qubit systems.

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Dr. **Wister Wei Huang** is an Assistant Professor at the National University of Singapore. His current research explores semiconductor quantum dots in silicon, bilayer graphene, and planar germanium for scalable quantum technologies. His group focuses on noise spectroscopy and correlation measurements in multi-qubit systems, as well as hybrid quantum devices that couple spin qubits to superconducting resonators for fast readout and long-range coupling. Before joining NUS, he was a Senior Scientist at ETH Zurich, where he led experiments on spin qubit readout in bilayer graphene quantum dots and planar germanium quantum dots. He received his PhD from the University of New South Wales, Australia, working on silicon spin qubits. His research has contributed to high-fidelity quantum logic in silicon, noise characterization in semiconductor qubits, and high-fidelity readout in emerging quantum dot platforms.

Day 2 / June 3 / 14:30-15:00

Measuring the current-phase relation in Josephson junction using superconducting resonators

Martin Berke[1,2], Zoltán Scherübl[1,2], Máté Sütő[1,2,3], Dávid Kóti[1,2,3], Bence Vasas[1,2,3], Gergő Fülöp[1,2], Endre Tóvári[1,4], Csaba Horváth[1,2], Szabolcs Csonka[1,2,3], and Péter Makk[1,4]*
1. Department of Physics, Institute of Physics, Budapest University of Technology and Economics, Műegyetem rkp. 3., H-1111 Budapest, Hungary
2. MTA-BME Superconducting Nanoelectronics Momentum Research Group, Műegyetem rkp. 3., H-1111 Budapest, Hungary
3. Institute of Technical Physics and Materials Science, HUN-REN Centre for Energy Research, Konkoly Thege Miklós út 29-33., H-1121 Budapest, Hungary
4. MTA-BME Correlated van der Waals Structures Momentum Research Group, Műegyetem rkp. 3., H-1111 Budapest, Hungary
*berke.martin@edu.bme.hu

Topological quantum computing architectures require the combination of superconductivity, spin-orbit interaction and electrostatic tunability, while scalability calls for two dimensional platforms. All these features are combined in semiconducting 2DEGs terminated by an epitaxial superconducting layer. Coupling and reading out the qubits necessitates the use of microwave resonators. Here we demonstrate the current phase relation (CPR) measurement in InAs 2DEG using an inductive coupling to a coplanar waveguide resonator, where both the SQUID and the resonators are fabricated from the epitaxial aluminium layer on the 2DEG [1]. Tuning the CPR by an external flux causes a change in the loading inductance of the resonator and hence a shift of the resonance frequency. Besides the CPR we could measure the Fraunhofer pattern of the junction using a larger magnetic field. This measurement scheme can be naturally extended to probe the nonlocal Josephson effect in hybrid 2DEG devices, where phase-coherent transport couples spatially separated superconducting leads [2]. In such geometries, resonator-based CPR readout would provide a sensitive way to detect nonlocal phase correlations and to distinguish them from conventional local Josephson contributions. We furthermore present first measurement results indicating the feasibility of extending this approach to the investigation of the nonlocal Josephson effect.

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I am a PhD student in the Department of Physics at the Budapest University of Technology and Economics. I work in experimental solid-state physics, and I am interested in semiconductor-superconductor hybrid platforms.

Day 2 / June 3 / 15:00-15:30

Characterization of low-energy states in Kitaev chains

R. Seoane Souto
M. Alvarado[1], R. Dourado[2], M. Leijnse[3], J. Danon[4], and R. Aguado[1]
1. Materials Science Institute of Madrid, ICMM-CSIC (Spain)
2. Instituto de Física de Sao Carlos, Universidade de Sao Paulo
3. Division of Solid State Physics and NanoLund, Lund University (Sweden)
4. Department of Physics, Norwegian University of Science and Technology (Norway)
Ruben.seoane@csic.es

Majorana bound states (MBS) are quasiparticles with non-Abelian statistics, making them highly attractive for both fundamental research and applications in quantum computing. The Kitaev model predicts the emergence of these states at the ends of a chain under specific parameter conditions [1]. In experimental realizations, artificial Kitaev chains can be engineered using quantum dot (QD) –superconductor arrays [2,3], see Figure 1 for a sketch. Recently, a minimal two-site version of such a chain has been demonstrated, revealing the possibility of non-topological MBSs appearing at specific points [4]. Characterizing the emergent MBSs is a key challenge in the field, crucial for advancing towards robust quantum applications. In this presentation, I will introduce various methods for qualitatively and quantitatively identifying Majorana sweet spots through local measurements [5-8]. These measurements enable the identification of parameter regimes with high MBS localization, see Fig. 1(a), an essential step toward Majorana-based devices in Kitaev chains [9-11].

Figure 1: Sketch of a minimal Kitaev chain formed by two QDs coupled via a superconducting segment, hosting well-localized (a), and overlapping MBSs (b).

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Rubén Seoane is a condensed-matter theorist working at the interface between nanoscience and superconductivity, with a focus on quantum devices for next-generation quantum technologies. His research has explored correlated phenomena in nanoscale systems, the physics of Andreev and Majorana bound states, and the design of robust qubit architectures and non-dissipative superconducting electronics. He did his PhD at the Autonomous University of Madrid (Spain), under the supervision of Prof. Alfredo Levy-Yeyati. In 2018, he moved as a postdoc to Lund University (Sweden) under the supervision of Prof. Martin Leijnse, being also external researcher at the Niels Bohr Institute (University of Copenhagen, Denmark). Since 2023, Rubén is a group leader at the Materials Science Institute of Madrid, belonging to the Spanish Research Council (ICMM-CSIC).

Day 2 / June 3 / 16:00-16:30

The integration of quantum dots toward scalable semiconductor spin qubits

Xiao-Fei Liu[1*], Zhi-Hai Liu[1], Ji-Yin Wang[1], and Hongqi Xu[1,2]
1. Beijing Academy of Quantum Information Sciences, Beijing 100193, China
2. Beijing Key Laboratory of Quantum Devices, Peking University, Beijing 100871, China
*liuxf@baqis.ac.cn

Gate-defined quantum dots (QDs) have become a promising candidate for fault-tolerant quantum computing because of the high-fidelity quantum operations and the intrinsic compatibility with complementary metal-oxide semiconductor (CMOS) technology [1]. However, the limited carrier mobility and fabrication fluctuations pose significant challenges for scalable semiconductor spin qubits. In this talk, we will introduce the remote interactions between gate-defined QDs under Floquet driving [2]. This system can realize the controlled-*i*SWAP gate by choosing suitable frequency, phase, and amplitude of the Floquet driving. Moreover, when we change the phase of the Floquet driving, the high-fidelity quantum state transfer between remote QDs is feasible through stimulated Raman adiabatic passage. This Floquet-driven QD system enables well-controlled interactions between remote QDs, which provides an efficient scheme toward scalable semiconductor spin qubits. In addition, we will introduce our recent progress, such as the vertical integration of QDs and a charge sensor.

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Xiao-Fei Liu is currently an assistant research scientist at Beijing Academy of Quantum Information Sciences (BAQIS), China. He received a PhD from Tsinghua University in 2017. Then, he worked as a postdoc at Beijing University of Posts and Telecommunications, and then at The University of Osaka. He joined BAQIS in 2023. His research interests focus on quantum information processing, especially semiconductor spin qubits.

Day 2 / June 3 / 16:30-17:00

Universal Logical Operations and Quantum Error Detection in a Silicon Quantum Processor

Yu He
International Quantum Academy, Shenzhen, China
hey@iqasz.cn

Silicon-based quantum computing has emerged as a highly promising platform within the broader landscape of quantum information systems, owing to the exceptionally long coherence times of spin qubits and the compatibility with established semiconductor manufacturing infrastructure. The research frontier has now shifted toward the development of large-scale, fault-tolerant architectures for logical qubits. In this talk, I will first introduce the atomic-scale fabrication technologies that form the foundation of our single-atom silicon quantum computing platform, including scanning tunneling microscope hydrogen lithography for device patterning at the atomic limit, deterministic single-donor placement via tip-induced electrochemistry, and the high-precision epitaxial growth of isotopically enriched silicon-28 to suppress magnetic noise from residual nuclear spins. Next, I will present two recent experimental progresses achieved within our laboratory. The first is the demonstration of a four-qubit error-detection circuit with stabilizers to detect arbitrary single-qubit errors in the [[2,0,2]] code. The encoded Bell-state entanglement information is recovered by postprocessing error correction. Second is the demonstration of the complete set of universal logical quantum operations on a silicon-based processor. Encoding two logical qubits across five phosphorus nuclear spins using the [[4,2,2]] code, we achieved fault-tolerant logical state preparation, logical single-qubit and two-qubit entangling gates, and, critically, a logical non-Clifford T gate. The realization of the T gate is particularly important, as it completes the universal gate set required for arbitrary quantum computation and magic distillation. We also implemented a variational quantum eigensolver to simulate the ground-state electronic structure of the water molecule, providing a prototypical validation of logical quantum computation. Taken together, these advances underscore the viability of donor-based qubits in silicon as a competitive pathway toward scalable fault-tolerant quantum computing. I will conclude by discussing future research on this platform, exploring the engineering challenges and strategic opportunities for large-scale integrated quantum processors.

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Dr. **Yu He** is a full-time researcher at the Shenzhen International Quantum Academy. His research field is quantum physics and quantum computation in solid-state systems. Currently, Dr. Yu is building a team to pursue frontier quantum computing techniques combined with fundamental physics in silicon quantum devices. In total, he has published 30 peer-reviewed journal articles (2 Nature, 2 Nature Photonics, 2 Nature Nanotechnology, and 10 Physical Review letters) and 5500 citations. H-index 22.

Day 2 / June 3 / 17:00-17:30

Superconducting Quantum Interference Devices based on InSb Nanoflag Josephson Junctions

Stefan Heun
Istituto Nanoscienze – CNR, NEST-SNS, Piazza San Silvestro 12, Pisa, Italy
stefan.heun@nano.cnr.it

High-quality III-V narrow bandgap semiconductor materials with strong spin-orbit coupling and large Lande g-factor provide a promising platform for next-generation applications in the field of high-speed electronics, spintronics, and quantum computing. InSb stands out due to its narrow bandgap, high carrier mobility, and small effective mass, making it very appealing for these applications. In fact, this material has attracted tremendous attention in recent years for the implementation of topological superconducting states.

In this context, the simultaneous breaking of time-reversal and inversion symmetry can lead to peculiar effects in Josephson junctions, such as the anomalous Josephson effect or supercurrent rectification, which is a dissipationless analog of the diode effect. Due to their potential impact in new quantum technologies, it is important to find robust platforms and external means to manipulate the above effects in a controlled way. We demonstrate that hybrid Josephson junctions made of high-quality InSb nanoflags [1] constitute a promising platform for supercurrent rectification due to its strong spin orbit coupling. The high quality of the devices enabled the observation of the diode effect in these Josephson junctions [2]. When subjected to an in-plane magnetic field, these devices enter a non-reciprocal transport regime, manifesting an asymmetry between positive and negative critical currents.

Furthermore, we fabricated (see Fig. 1) and investigated superconducting quantum interference devices (SQUIDs) based on InSb nanoflag Josephson junctions [3]. We measured interference patterns in both symmetric and asymmetric geometries. The interference patterns in both configurations can be modulated by a back-gate voltage, a feature well reproduced through numerical simulations. The observed behavior aligns with the skewed current-phase relations of the Josephson junctions, demonstrating significant contributions from higher harmonics. Finally, we assess the flux-to-voltage sensitivity of the SQUIDs to evaluate their performance as magnetometers.

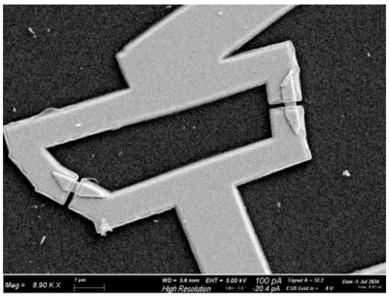

Figure 1: Top-view scanning electron microscopy image of a SQUID in symmetric geometry.

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Stefan Heun is Research Director at the Istituto Nanoscienze of the Italian National Research Council CNR. He received his diploma in physics at the University of Hannover (Germany), where he investigated in the group of Prof. M. Henzler the initial stages of epitaxial growth of silicon on Si(100). In 1993 he received his Ph.D. in the same group, working on the magneto-conductivity of monolayer-thin films of Ag, Pb, and Au deposited on Si(111).

In 1993, he joined the Interdisciplinary Research Laboratories of the Japanese Telecom NTT in Tokyo (Japan), where he studied the surface passivation of III-V semiconductors using synchrotron radiation.

In 1995, he moved as a Marie Curie Fellow to the Materials Division of the TASC (now IOM) lab in Trieste (Italy), where he worked on the engineering of heterostructure interfaces. In 1997, he became a beam line scientist at the Sincrotrone Trieste, where he was appointed responsible of the Nanospectroscopy Beamline, at which he also performed his research on low-dimensional systems.

Finally, in 2004 he joined the CNR, first in Trieste and since October 2006 at Istituto Nanoscienze in Pisa (Italy). In these last years, his work focuses on the use of scanning probe microscopy, in particular scanning gate microscopy (SGM) and scanning tunneling microscopy (STM), for the study of two-dimensional semiconductors and graphene nanostructures.

Stefan Heun has co-authored more than 200 papers and has given more than 120 invited presentations and seminars. To date (April 2026) his papers have been cited over 4500 times. h-index: 35. He is Adjunct Professor at Scuola Normale Superiore in Pisa and at the University of Pisa, where he teaches on *Nanostructured Materials*.

Day 3 / June 4 / 08:30-09:00

Experimental exploration of the Fu-Kane scheme for topological quantum computation

Li Lu
Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China
lilu@iphy.ac.cn

The Fu-Kane scheme for topological quantum computing leverages p-wave-like superconductivity emerging at the interface between an s-wave superconductor and a topological insulator (TI) to form Josephson tri-junctions [1], and applies surface code techniques to a tri-junction network to realize universal quantum computation [2]. In the past decade, we carried out systematic experimental investigations on Josephson devices fabricated on the surfaces of Bi_2Te_3-family materials. First, we confirmed that the Josephson single junctions thus constructed exhibit perfectly transparent transport behavior [3]. Then, we showed that a topological boundary state can be controllably created in corner junctions [4] and tri-junctions [5], manifested as the closure of the local minigap, which is a signature of the appearance of a Majorana zero mode (MZM). Furthermore, we showed that the minigap reopens when two tri-junctions are brought together [6], in agreement with the expected effect of coupling between the MZMs. Lastly, we explored the exchange operation of two MZMs in an envelope-shaped device consisting of four tri-junctions [7]. Our studies suggest that TI-based Josephson devices may provide a promising platform for hosting and braiding MZMs.

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Professor **Li LU** received his B.S degree from Nanjing University in 1982 and a Ph. D. from the Institute of Physics, Chinese Academy of Sciences (IOP-CAS) in 1992. He worked as a research associate at University of California, Berkeley during 1992-1995. He then joined IOP-CAS in 1995 and became a full professor there in 1996. Prof. Li LU ever served as the founding director of the Laboratory for Extreme Physical Conditions, the director of the Laboratory for Solid-state Quantum Information and Computation, and the deputy director of IOP. He is currently the director of Daniel Chee Tsui Laboratory and the director of the Huairou branch, IOP-CAS. Prof. Li LU's current research interests include topological superconductivity and Josephson devices for topological quantum computation.

Day 3 / June 4 / 09:00-09:30

Experiments on Kitaev chains in semiconductor–superconductor hybrids

Francesco Zatelli[*1], *Nick van Loo*[1], *Bart Roovers*[1], *Antonio Lombardi*[1], *Vincent Sietses*[1],
Florian Bennebroek Evertsz'[1], *Pablo Cova Fariña*[1], *Mats de Jong*[1], *Ashley Ang*[1],
Bhoomika Tanikonda[1], *and Leo Kouwenhoven*[1]
1. QuTech, Delft University of Technology, Lorentzweg 1, Delft, The Netherlands
*f.zatelli@tudelft.nl

Majorana zero modes encode quantum information non-locally, offering a route toward qubits with intrinsic protection against noise. A promising experimental approach is to realize Kitaev chains in semiconductor–superconductor quantum-dot arrays, where the relevant parameters can be tuned electrostatically.

In this talk, I will describe experiments on nanowire-based Kitaev chains, starting from the basic building blocks and progressing toward longer chains. I will discuss how these devices are tuned, how their fermion parity can be measured using quantum capacitance readout, and how these ingredients form the basis for future demonstrations of a Majorana qubit.

Francesco Zatelli is a PhD researcher in Leo Kouwenhoven's group at QuTech, Delft University of Technology, working on semiconductor–superconductor hybrid devices for Majorana-based quantum computing. His research focuses on the realization and control of Kitaev chains toward the demonstration of a Majorana qubit.

Day 3 / June 4 / 09:30-10:00

Gate- and Microwave-Controlled Josephson Transport in III-V Semiconductor Hybrid Josephson Devices

Xing-Jun Wu[1*] and H. Q. Xu[1,2*]
1. Beijing Academy of Quantum Information Sciences, Beijing 100193, China
2. Peking University, Beijing 100871, China
*wuxj@baqis.ac.cn

III–V semiconductors such as InSb and InAs have attracted considerable attention as promising platforms for realizing topological superconductivity. In this talk, I will present our recent progress on Al–InSb nanosheet hybrid devices, focusing on how gate- and microwave-based control can be used to probe Josephson dynamics, engineer higher-harmonic superconducting transport, and access correlated Andreev physics in confined quantum-dot systems.

First, I will discuss microwave Josephson spectroscopy in Al–InSb nanosheet Josephson junctions. Although a missing first Shapiro step is often regarded as a signature of the fractional AC Josephson effect, our results show that it can also emerge in a topologically trivial regime. We demonstrate that sharp superconducting switching and the resulting measurement blind region serve as a ubiquitous non-topological origin of the missing step [1]. Next, I will introduce gate- and flux-controlled Josephson transport in nanosheet SQUID interferometers. We observe a gate- and flux-tunable superconducting diode effect, where higher harmonics in the current–phase relation play an essential role. Moreover, microwave irradiation provides an additional dynamic control knob, enabling reversible polarity switching of the superconducting diode [2]. Then, I will further present the correlated Andreev physics observed in superconductor-coupled nanosheet quantum dots. Electrostatic confinement enables access to the few-electron regime, where Kondo correlations and superconductivity coexist and compete. By tuning the coupling strength between the quantum dot and superconducting leads, we observe a clear singlet–doublet quantum phase transition [3]. Finally, I will briefly introduce gate- and microwave-controlled superconducting transport in InAs-based devices, including microwave-assisted unidirectional superconductivity in nanowires [4] and gate-tunable Josephson diode effects in nanosheet junctions [5]. These nonreciprocal supercurrent phenomena provide a promising route toward directional superconducting components and low-dissipation functionalities for future superconducting circuits.

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Xingjun Wu is currently an Assistant Research Scientist at the Beijing Academy of Quantum Information Sciences, China. He received his Ph.D. in condensed matter physics from Peking University in 2017. After two years of postdoctoral research at Peking University, he officially joined the Beijing Academy of Quantum Information Sciences in 2019. His current research interests include topological quantum devices based on semiconductor–superconductor hybrids.

Day 3 / June 4 / 10:30-11:00

Quantum entanglement between NV centers and their application

Ya Wang
School of Physics, University of Science and Technology of China.
ywustc@ustc.edu.cn

The nitrogen-vacancy (NV) center in diamond is a leading solid-state platform for quantum information science. A central challenge in scaling this system is establishing robust entanglement between separate NV centers. Here, we report key progress by engineering diamond NV centers to demonstrate direct spin-spin entanglement via magnetic dipole interaction, a critical step towards scalable spin systems. We further apply this resource in an immediate application: entanglement-enhanced sensing, where the entangled pairs achieve a measurement sensitivity surpassing the capabilities of single NV centers.

Prof. **Ya Wang** is from School of Physics, University of Science and Technology of China. Prof. Wang's research activities are focused on spin quantum devices and applications.

Day 3 / June 4 / 11:00-11:30

Hamiltonian estimation in semiconductor spin qubits

J. Danon[1], F. Berritta[2,3,4], J. Benestad[1], J. Krzywda[5] and F. Kuemmeth[2,6,7]*
1. Norwegian University of Science and Technology
2. Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen
3. Research Laboratory of Electronics, Massachusetts Institute of Technology
4. NNF Quantum Computing Programme, Niels Bohr Institute, University of Copenhagen
5. Lorentz Institute for Theoretical Physics & LIACS, Universiteit Leiden
6. Institute of Experimental and Applied Physics, University of Regensburg
7. QDevil, Quantum Machines, 2750 Ballerup, Denmark
*jeroen.danon@ntnu.no

In this talk, I will present progress we made in developing adaptive Bayesian techniques for estimating slowly fluctuating Hamiltonian parameters. Taking the capabilities of state-of-the-art FPGA-based control hardware as a boundary condition, we explore strategies for efficient Hamiltonian estimation, including the potential use of on-chip neural networks and taking into account the physics of the fluctuating parameters [1]. The simplified adaptive scheme we develop is memory-efficient and can bring more than an order of magnitude improvement in estimation accuracy compared to the standard approach. We first use such Bayesian estimation protocols in experiments to track the slowly fluctuating Overhauser gradient in singlet-triplet spin qubits, showing indeed clear improvement in estimation quality when using adaptive and physics-informed methods [2,3]. We then extended the use of the methods to Hamiltonian and "Lindbladian" parameter estimation in other qubit platforms as well [4,5].

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Jeroen Danon obtained his PhD in theoretical condensed matter physics from the Delft University of Technology in 2009. After that he was a postdoctoral researcher at the Free University Berlin (2009-2012) and at the Niels Bohr Institute in Copenhagen (2012-2016). Since 2016 he has his own group at the Norwegian University of Science and Technology in Trondheim.

Day 3 / June 4 / 11:30-12:00

Superconducting spin qubits

Ramón Aguado

The Andreev spin qubit (ASQ), formed by the spin of a quasiparticle trapped in a quantum dot Josephson junction, represents a promising hybrid semiconductor-superconductor qubit [1]. Integrating this superconducting spin qubit into a transmon circuit enables intrinsic spin-supercurrent coupling, providing a natural interface with circuit quantum electrodynamics for coherent control, high-fidelity readout, and strong qubit-qubit interactions [2,3]. However, ASQ performance is currently limited by spin decoherence. In this talk I will discuss two noise-mitigation strategies. The first strategy involves shunting the ASQ with a linear inductor, which dramatically enhances coherence by separating spin-qubit states into distinct potential wells in phase space, nearly eliminating wavefunction overlap. This yields the inductively protected Andreev (IPA) spin qubit [4], which is analogous to a heavy fluxonium qubit biased close to half a flux quantum, featuring a low-frequency ground-state manifold and large anharmonicity, but with each potential minimum hosting a well-defined spin state. Consequently, the IPA qubit uniquely combines the long coherence of a protected superconducting qubit with the operational advantages of a spin degree of freedom. The second strategy addresses the primary dephasing mechanism, namely spin fluctuations, by selecting a platform lacking nuclear spins. To this end, I will discuss proximitized germanium (Ge) as a leading hybrid semiconductor-superconductor platform where hole-based quantum dots [5] open new avenues for Andreev qubit physics [6].

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Ramón Aguado is a Full Professor at the Quantum Advanced Research Center (QuARC) and Institute of Materials Science in Madrid (ICMM) both belonging to the Spanish

Research Council CSIC. He has previously worked at Rutgers State University of New Jersey (United States) and Delft University of Technology (Netherlands). His research focuses on the theoretical study of quantum materials and their applications in quantum technologies. He has served as Principal Investigator on numerous research grants and is co-author of around 150 scientific articles, as well as several review and popular science articles. In recent years, his scientific impact has been reflected in high-impact publications, many of them in collaboration with prestigious international experimental groups, and his work has been recognized in various international rankings as a highly cited scientist.

In addition to his research work, he serves as Coordinator of the Quantum Physics and Materials Program in the Spanish State Research Agency (AEI) of the Spanish Ministry of Science. He is the President of the Division of Condensed Matter Physics (DCMP) of the Royal Spanish Physical Society (RSEF).

Poster List

1. **Transport Dynamics in Semiconductor Nanowire Junctions Governed by Non-Sinusoidal Current-Phase Relation and Nonlinear Dissipation**

Chuanchang Zeng

Beijing Academy of Quantum Information Sciences, China

2. **Microwave Spectroscopy of Andreev Bound States in an InAs nanowire**

Csaba Horváth

Department of Physics, Institute of Physics, Budapest University of Technology and Economics, Hungary

3. **Atomically Flat Al/Ge Heterostructures and Their Interface Lattice Structures**

Ding-Ming Huang

Beijing Academy of Quantum Information Sciences, China

4. **Topological Transition and Edge-Mode Superconductivity in Electric-Field-Tuned InSb Nanosheet Josephson Junctions**

Fangqi Cai

Beijing Academy of Quantum Information Sciences, China

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Beijing Academy of Quantum Information Sciences, China

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Beijing Academy of Quantum Information Sciences, China

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Beijing Academy of Quantum Information Sciences, China

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Beijing Academy of Quantum Information Sciences, China

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Jie-Yin Zhang

Dongguan Institute of Materials Science and Technology Chinese Academy of Sciences, China

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J.L. del Olmo N

Instituto de Ciencia de Materiale de Madrid (ICMM), Consejo Superior de Investigaciones Científicas (CSIC), Spain

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Beijing Academy of Quantum Information Sciences, China

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Beijing Academy of Quantum Information Sciences, China

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Instituto de Ciencia de Materiale de Madrid (ICMM), Consejo Superior de Investigaciones Científicas (CSIC), Spain

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Beijing Academy of Quantum Information Sciences, China

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Lund University, Sweden

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Department of Physics and Astronomy, University College London, United Kingdom

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Beijing Academy of Quantum Information Sciences, China

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Instituto de Ciencia de Materiale de Madrid (ICMM), Consejo Superior de Investigaciones Científicas (CSIC), Spain

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YuXiao Song

Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, China

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Instituto de Ciencia de Materiales de Madrid (ICMM - CSIC), Spain

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Zhengqing Wei

Beijing Academy of Quantum Information Sciences, China

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Zhi-Hai Liu

Beijing Academy of Quantum Information Sciences, China

1. Transport Dynamics in Semiconductor Nanowire Junctions Governed by Non-Sinusoidal Current-Phase Relation and Nonlinear Dissipation

Chuanchang Zeng

A comprehensive description of realistic semiconductor nanowire Josephson junctions requires treating the current–phase relation (CPR) and the dissipative quasiparticle current (DQC) on equal microscopic footing. By integrating these microscopically derived currents into a generalized phase-dynamics model, we find that it naturally captures many key transport signatures frequently observed in experiments, including resonant structures across Shapiro steps, suppression of lower-order integer steps, and the emergence of fractional Shapiro steps. Using a phenomenological DQC model with tunable multiple Andreev reflection peak heights, we establish a direct link between these resonant structures and the underlying MAR processes. Furthermore, accounting for the finite momentum of Cooper pairs reveals the non-reciprocity of the dissipative quasiparticle current, $I(V) \neq I(-V)$. This emergent property gives rise to a superconducting diode effect that reaches ideal 100% efficiency under microwave radiation. We expect this unified framework to serve as a quantitative tool for analyzing the transport properties of superconducting nanowire SNS junctions.

2. Microwave Spectroscopy of Andreev Bound States in an InAs nanowire

Csaba Horváth [1,2,*], Mátyás Kocsis [1,2], Zoltán Scherübl [1,2], Gergő Fülöp [1,2], Péter Makk [1,3], Szabolcs Csonka [1,2], O.O. Shvetsov [4], A. Geresdi [4], Jesper Nygård [5] and Thomas Kanne [5]

[1] *Department of Physics, Institute of Physics, Budapest University of Technology and Economics, Műegyetem rkp. 3., H-1111 Budapest, Hungary*
[2] *MTA-BME Superconducting Nanoelectronics Momentum Research Group, Műegyetem rkp. 3., H-1111 Budapest, Hungary*
[3] *MTA-BME Correlated van der Waals Structures Momentum Research Group, Műegyetem rkp. 3., H-1111 Budapest, Hungary*
[4] *Department of Microtechnology and Nanoscience, Chalmers University of Technology, SE-41296 Gothenburg, Sweden*
[5] *Niels Bohr Institute, Center for Quantum Devices, University of Copenhagen, Universitetsparken 5, DK-2100 Copenhagen O, Denmark*

Superconductor-semiconductor hybrid devices are promising platforms for the realization of qubit architectures. In these devices, the quantum information is stored in Andreev bound states, formed in Josephson junctions [1]. We investigated and characterized a device consisting of an InAs nanowire weak link with aluminium contacts, embedded in a superconducting loop and coupled to a lumped-element resonator patterned from a thin NbTiN film [2]. We performed microwave spectroscopy while tuning the Andreev bound states via electrostatic gating, flux biasing and an in-plane magnetic field.

[1] M. Hays et al., Coherent manipulation of an Andreev spin qubit. Science 373,430-433(2021)
[2] O.O. Shvetsov et al., arXiv:2502.09243 (2025).

*Email address: csaba.horvath1818@gmail.com

3. Atomically Flat Al/Ge Heterostructures and Their Interface Lattice Structures

Ding-Ming Huang[1*], Jian-Huan Wang[1], Jian-Jun Zhang[2], and Hongqi Xu[1,3]
[1]*Beijing Academy of Quantum Information Sciences, Beijing, 100193, China*
[2]*Beijing National Laboratory for Condensed Matter Physics and Institute of Physics, Chinese Academy of Sciences, Beijing, 100190, China*
[3]*Beijing Key Laboratory of Quantum Devices, Peking University, Beijing, 100871, China*
*E-mail: huangdm@baqis.ac.cn

Superconductor/semiconductor (super/semi) heterostructures are frontier material platforms for realizing Josephson field-effect transistors, superconducting diodes, Andreev spin qubits, and topological qubits. Single-crystalline super/semi heterostructures with atomically sharp interfaces can effectively reduce the effects of scattering arising from complex interfacial structures, thereby providing an ideal platform to elucidate the underlying physical mechanisms in fabricated quantum devices. Here, we report that single-crystalline aluminum (Al) thin films with a face-centered cubic lattice were grown on diamond-structure germanium (Ge) substrates via molecular beam epitaxy. An atomically flat interface with commensurately matched Al and Ge lattices was achieved. Scanning tunneling spectroscopy measurements revealed that the energies of the quantum well states detected at different lateral locations of the Al film remained consistent, confirming the atomic-scale flatness of the interface. Second-derivative conductance spectra demonstrated a spatially uniform electron-phonon coupling strength, confirming the homogeneity of the Al film. By probing the quantum well states in the material via scanning tunneling microscopy (STM), the buried interfacial structure and defects were "visualized" from the material surface. It was observed that the peak width of the quantum well states was modulated by the interfacial lattice, exhibiting laterally periodic variations. A physical model based on the Fabry-Perot interferometer was established to simulate the quantum well peaks, revealing that the variation in the peak width originates from the local change in electron reflective scattering, which was modulated by the detailed commensurate lattice structures at the Al/Ge interface. This study presents a high-quality Al/Ge heterojunction and proposes a new, non-destructive method for characterizing the interface lattice structures in super/semi heterostructures.

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4. Topological Transition and Edge-Mode Superconductivity in Electric-Field-Tuned InSb Nanosheet Josephson Junctions

Fangqi Cai[1], Dong Pan[2], Jiyin Wang[1*], Xingjun Wu[1*], and Hongqi Xu[1,3*]
1. Beijing Academy of Quantum Information Sciences, Beijing 100193, China
2. State Key Laboratory of Semiconductor Physics and Chip Technologies, Institute of Semiconductors, Chinese Academy of Sciences, Beijing 100083, China;
3. Beijing Key Laboratory of Quantum Devices, Peking University, Beijing 100871, China;
*wang_jy@baqis.ac.cn
*wuxj@baqis.ac.cn
*hqxu@pku.edu.cn

Topological superconductivity is an exotic state of matter that supports Majorana zero modes and is predicted to occur in the surface states of three-dimensional systems, the edge states of two-dimensional systems, and in one-dimensional wires. One important direction for realizing topological superconductivity is through the edge states of quantum spin Hall insulators. In two-dimensional InAs/GaSb heterostructures, edge-mode superconductivity has been experimentally observed, providing a promising platform for further exploration of topological superconductivity.[1] Theoretical studies also predict that InSb nanosheets can be tuned by an electric field to realize a quantum spin Hall state.[2] Compared with one-dimensional InSb nanowires, where s-wave superconductors and external magnetic fields are used to induce topological superconductivity, this approach offers a new route toward magnetic-field-free topological superconductivity in InSb nanosheets.

In this work, we fabricate high-quality dual-gated InSb nanosheet Josephson junctions with Al superconducting contacts, where the dual gates allow continuous tuning of the InSb band structure through applied electric fields, potentially inducing a topological transition. We demonstrated gate-tunable Josephson supercurrent with a maximum switching current of approximately 150 nA. Under perpendicular magnetic fields, we observed clear Fraunhofer diffraction patterns in the critical current, which confirm the bulk transport properties in the Josephson junction. In the phase diagram under varying electric fields, we observed a transition from the electron-dominated regime through the bandgap to the hole-dominated regime. With continuous dual-gate modulation, the bandgap region gradually shrinks, suggesting a possible approach toward an inverted band state. These results provide essential guidance for further exploration of the quantum spin Hall insulator properties and the investigation of edge-mode superconductivity in InSb nanosheets.

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5. Anomalous High-Order Fractional Shapiro Steps in an Al/InAs Nanowire Josephson Junction

Haitian Su[1,2,3*], Ji-Yin Wang[1], Han Gao[1,2], Yi Luo[1,2,3], Weijie Li[1,2,4], Shili Yan[1], Xingjun Wu[1], Dong Pan[5], Jianhua Zhao[5], Po Zhang[1], and H. Q. Xu[1,2]

[1]*Beijing Academy of Quantum Information Sciences, Beijing 100193, China*

[2]*Beijing Key Laboratory of Quantum Devices, Peking University, Beijing 100871, China*

[3]*Institute of Condensed Matter and Material Physics, School of Physics, Peking University, Beijing 100871, China*

[4]*Academy for Advanced Interdisciplinary Studies, Peking University, Beijing 100871, China*

[5]*State Key Laboratory of Superlattices and Microstructures, Institute of Semiconductors, Chinese Academy of Sciences, P.O. Box 912, Beijing 100083, China*

*suht@baqis.ac.cn

Shapiro steps are quantized DC voltage signatures observed in a periodically driven superconducting weak link [1]. Fractional steps may arise due to mechanisms like nonsinusoidal current-phase relation or nonequilibrium transport [2,3], and are energetically associated with the transfer of multiple Cooper pairs. Although half-integer steps have been widely documented, higher-order fractional steps are still relatively under explored. Here, we report the observation of unconventional multiple high-order fractional Shapiro steps in an epitaxial Al/InAs nanowire Josephson junction. Such a Josephson junction was employed to explore microwave-assisted unidirectional superconductivity [4]. In the present work, we focus on the detection of fractional Shapiro steps and show that the number of observed fractional Shapiro steps increases as the microwave driving frequency increases. Up to nine fractional steps are observed between steps zero and one at 20 GHz. The fractional steps are stable against several experimental knobs. The width of the fractional step does not exhibit a clear decreasing trend with increasing fractional order, contradicting typical theoretical expectations. Our work highlights a high-quality superconductor-semiconductor nanowire hybrid system which could be used as an ideal platform for probing exotic quantum dynamics under periodic driving.

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6. Gate-Tunable Supercurrent in Planar Josephson Junctions Made from an Epitaxially grown Ge Quantum Well-Al Heterostructure

Han Gao[1,*], Jie-Yin Zhang[2,3], Hai-Tian Su[1], Jian-Huan Wang[1], Ding-Ming Huang[1], Jian-Jun Zhang[2,3], Ji-Yin Wang[1], and Hongqi Xu[1,4,*]
1. Beijing Academy of Quantum Information Sciences, Beijing 100193, China
2. Songshan Lake Materials Laboratory, Guangdong 523808, China
3. Beijing National Laboratory for Condensed Matter Physics and Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China
4. Beijing Key Laboratory of Quantum Devices, Peking University, Beijing 100871, China
*gaohan@baqis.ac.cn; hqxu@pku.edu.cn

Owing to strong spin-orbit coupling, weak hyperfine interaction, and ultrahigh hole mobility, two-dimensional germanium quantum wells (Ge QWs) exhibit an immense potential in the field of topological superconductivity [1,2]. While previous studies have demonstrated the feasibility of the materials for constructing superconducting hybrid devices, to achieve a large 'hard' superconducting gap in Josephson junction devices made from them remains a formidable challenge. Motivated by recent works on tuning the superconducting gap via barrier thickness engineering [3], we employed molecular beam epitaxy (MBE) to conduct *in situ* epitaxial growth of Al directly on Ge quantum wells and deliberately omitted growth of a SiGe barrier layer. Specifically, a 5 nm Al film was deposited onto a 16 nm Ge QW wafer immediately after growth of a 1 nm Si layer. Incorporating this 1 nm Si interlayer in the heterostructures is essential to suppress Ge-Al inter-atomic diffusion. High-resolution transmission electron microscopy measurements confirm that this fully *in situ* growth process yields high crystalline quality materials with atomically sharp and ultra-clean interfaces. Utilizing these high-quality heterostructures, we fabricated Josephson junctions by etching a trench in Al film and then depositing a thin layer of Al_2O_3 and a Ti/Au gate. Low temperature transport measurements were carried out on the fabricated devices. It was observed that the Josephson junctions exhibit a gate-tunable supercurrent and the junction transparency can be as high as 80%. The magnetic field dependence of the supercurrent was found to display a classic Fraunhofer pattern, indicating a uniform supercurrent distribution across the channel. We also mapped out the evolution of the induced superconducting gap under varying magnetic fields and temperatures, extracting an induced gap of ~180 μeV, along with a critical magnetic field of 35 mT and a critical temperature of 1.35 K. In conclusion, we have successfully achieved epitaxial growth of an Al film on a Ge quantum well and fabricated planar Josephson junctions on this novel platform. This work establishes an experimental foundation for engineering Ge QW-Al heterostructures via MBE, thereby propelling the study of topological superconductivity in two-dimensional Ge hole gas systems.

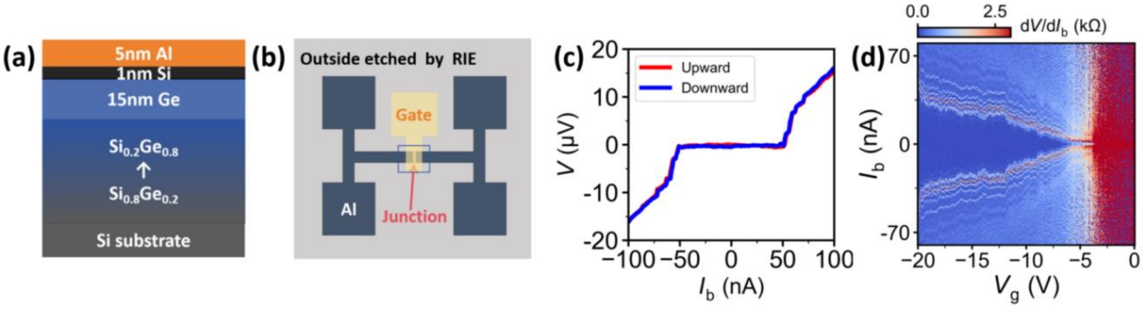

Fig. 1. (a) Cross-sectional schematic of a Ge QW-Al heterostructure. (b) The schematic of a Josephson junction device. (c) Measured voltage V across the junction as a function of current bias I_b. (d) Differential resistance dV/dI_b vs I_b and V_g.

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7. Multi-Qubit Gates Over an Inhomogeneous Array of Quantum Dots

J. Qi[1*], Z. Liu[1], and H. Q. Xu[1,2]

1 Beijing Academy of Quantum Information Sciences, Beijing 100193, China

2 Beijing Key Laboratory of Quantum Devices, Peking University, Beijing 100871, China

**qija@baqis.ac.cn*

The prospect of large-scale quantum computation with an integrated chip of semiconductor spin qubits is imminent as technology improves. This invites us to think beyond the traditional two-qubit-gate framework [1,2] and consider a naturally supported "instruction set" of multi-qubit gates [3]. In this work, we theoretically investigate such a family of multi-qubit gates implementable over an array of quantum dots by DC evolution (see Fig. 1). A useful representation of the computational Hamiltonian is proposed for a dot array with strong spin-orbit couplings, distinctive g-factor tensors and varying interdot couplings. Adopting a perturbative treatment, we model a multi-qubit DC gate by the first-order dynamics in the qubit frame and develop a detailed formalism for decomposing the resulting gate, estimating and optimizing the coherent gate errors with appropriate local phase shifts for an arbitrary array connectivity. Examples of such multi-qubit gates and their applications in quantum error correction and quantum algorithms are also explored, demonstrating their potential advantage in accelerating complex tasks and reducing overall errors.

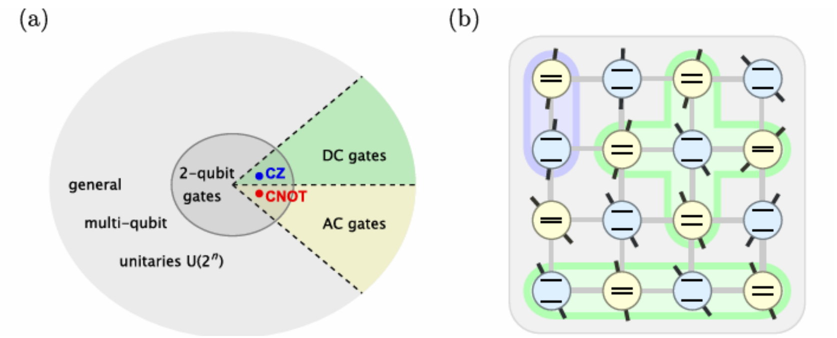

Fig. 1. (a) A classification diagram of quantum gates, which reveals that the CZ gate for spin qubit can be extended to a much broader set of DC gates. (b) Examples of feasible multi-qubit gates (in green shade) that can be implemented on a spin qubit

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8. Controlled Growth of High Mobility Planar Ge Nanowires for Semiconductor Quantum Computing

Jian-Huan Wang[1, *], Jian-Jun Zhang[2] and Hongqi Xu[1, 3]
1. Beijing Academy of Quantum Information Sciences, Beijing 100193, China
2 Beijing National Laboratory for Condensed Matter Physics and Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China
3 Beijing Key Laboratory of Quantum Devices and School of Electronics, Peking University, Beijing 100871, China
* wangjianhuan@baqis.ac.cn

Driven by research on semiconductor quantum computing, the fabrication of germanium (Ge) nanowires is evolving from self-assembled growth with random in-plane orientation to addressable localized growth [1-3]. However, the self-assembled growth of Ge nanowires typically requires high temperatures (above 500 °C). This process induces Si-Ge interdiffusion, leading to the formation of SiGe alloys within the nanowires and limiting their electrical performance. Here, we present a new method for the controllable growth of pure Ge nanowires [4]. Using a strain-relaxed SiGe/Si(001) patterned substrate as a mask, we achieve localized self-assembled growth of Ge nanowires composed of nearly pure Ge at a low temperature of 290 °C by molecular beam epitaxy. Transistor devices fabricated from this material exhibit excellent hole conduction in low-temperature electrical transport measurements, with a mobility as high as 7000 cm^2/Vs, surpassing the previous record held by the V-L-S method grown Si-Ge core/shell nanowires [5]. Quantum dot devices based on this material show clear Coulomb diamonds for single quantum dots and a hexagonal honeycomb pattern characteristic of double quantum dots, preliminarily demonstrating the potential of this material for scaling up to multiple qubits. Recently, using aluminum as source-drain electrodes, we successfully fabricated gate-controlled Josephson junction devices and observed supercurrent for the first time in planar Ge nanowires [6]. These results represent a key step toward the development of hybrid superconducting quantum devices based on Ge nanowire materials.

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9. Dislocation- and Crosshatch-Free High-Mobility Silicon Two-Dimensional Electron Gases

Jie-Yin Zhang,[1,2] * Fang-Ze Liu,[2] Ming Ming,[1,2] Liang-Xin Liao,[1] Xin-Yu Zhou,[2] Jian-Jun Zhang[2,3]*

[1] Dongguan Institute of Materials Science and Technology Chinese Academy of Sciences, Dongguan, Guangdong 523808, China

[2] Beijing National Laboratory for Condensed Matter Physics, Institute of Physics Chinese Academy of Sciences, Beijing 100190, China

[3]Hefei National Laboratory, Hefei 230088, China

*E-mail: zhangjieyin@dimst.ac.cn jjzhang@iphy.ac.cn

We report the realization of dislocation- and crosshatch-free Si/SiGe heterostructures grown by molecular beam epitaxy on transferred strain-relaxed SiGe films on Si(001). The transferred SiGe films (2×2 mm^2) are homogeneous, fully strain-relaxed, and free of threading dislocations and crosshatch patterns. The SiGe/Si/SiGe two-dimensional electron gas (2DEG) exhibits an exceptionally high mobility of 5.18×10^5 $cm^2/V\cdot s$, surpassing previously reported values. A low percolation density of 5.83×10^{10} cm^{-2} indicates minimal disorder, while a large Dingle ratio (~30) reveals background impurity scattering as the dominant mobility-limiting mechanism. Atomic force microscopy shows an atomically flat surface (RMS roughness 0.136 nm), and Raman mapping demonstrates a highly homogeneous strain distribution with a standard deviation of only 1.07%. Our results establish Si/SiGe heterostructures on transferred SiGe nanofilms as a promising platform for high-performance Si-based quantum devices.

10. Inductively Protected Andreev Spin Qubit (IPA)

J.L. del Olmo N.[1*], F.J Matute-Cañadas[2], A. Levi Yeyati[2], Rubén Seoane [1], Ramón Aguado[1]

1. Instituto de Ciencia de Materiale de Madrid (ICMM), Consejo Superior de Investigaciones Científicas (CSIC), Sor Juana Inés de la Cruz 3, 28049 Madrid, Spain.

2. Departamento de Física Teórica de la Materia Condensada, Instituto Nicolás Cabrera and Condensed Matter Physics Center (IFIMAC). Universidad Autónoma de Madrid, 28049 Madrid, Spain.

*Jose.delolmo@csic.es

The susceptibility to environmental fluctuations of quantum spin qubits, leading to decoherence and relaxation, has motivated the search for protected qubits that minimize sensitivity to these perturbations, to extend coherence times, and improve the scalability of quantum processors. Recent experiments implemented an Andreev Spin Qubit (ASQ): a quantum spin embedded in a superconducting circuit [1,2,3]. The system, implemented in semiconductor-superconductor platform, is susceptible to different sources of noise that limit the coherent times [2,3]. Here, we present a new Inductively Protected-Andreev-spin qubit design based on a superconductor–semiconductor hybrid platform of [4]. Shunting the ASQ with an inductor, see sketch in **Fig. 1a**, enables to separate spin states into different minima, controlled by the ratio (**$\tilde{\mathbf{E}}_\mathbf{J}$/ $\mathbf{E}_\mathbf{L}$**). This wavefunction disjunction illustrated in **Fig. 1b,** would increase magnetic field noise protection and enhance coherence times of the qubit.

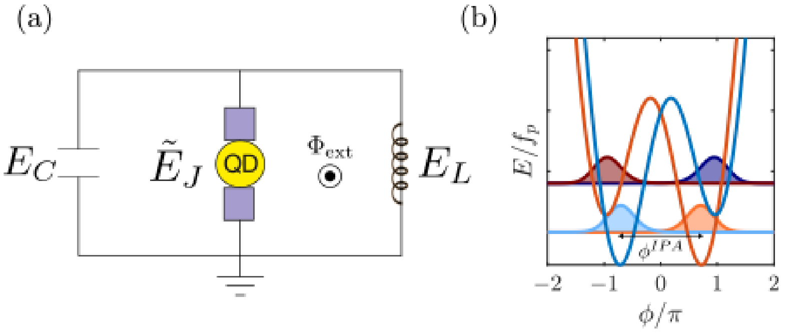

Figure 1a. Schematic model of the experimental setup. Here, **$\mathbf{E}_\mathbf{C}$**, **$\tilde{\mathbf{E}}_\mathbf{J}$**, and **$\mathbf{E}_\mathbf{L}$** denote the capacitive, Josephson, and inductive energies, respectively, and Φ_{ext} is the external flux threading the loop. **Figure 1b.** First four states of the system normalized by the plasma frequency. Protection is achieved when the harmonic potential separates the lowest spin ground states with high anharmonicity and the Josephson potential maintains a sufficiently high barrier to suppress inter-well tunneling.

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11. Low charge noise quantum dots in Ge/SiGe heterostructures

Junhang Liu[1,2*], Ding-Ming Huang[1], Yi Luo[1], Han Gao[1], Xiao-Fei Liu[1], Ji-Yin Wang[1],

and H. Q. Xu[1,3]

1. Beijing Academy of Quantum Information Sciences, Beijing 100193, China
2. Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China
3. Beijing Key Laboratory of Quantum Devices, Peking University, Beijing 100871, China
*liujh2023@baqis.ac.cn

In quantum computing, semiconductor quantum computing has the advantages of compatibility with CMOS technology and small size of devices, making it a potential platform for realizing universal quantum computing[1]. Among different types of semiconductor qubits, spin qubits based on nuclear-free spin group IV materials have attracted much attention due to the long decoherence time. Among group-IV materials, germanium exhibits superior properties including small effective mass, anisotropic g-factor, sweet-spot operation, strong spin-orbit coupling, and great potential for long-range qubit coupling via spin shuttling and hopping[2]. These properties enable rapid electrical hole spin qubit operations, rendering Ge an excellent candidate for constructing spin qubits. However, charge noise remains a critical challenge throughout the computational process, limiting the performance of quantum information processing. Here, we employ three distinct methods to quantify 1/f noise in multiple quantum dot devices fabricated on Ge/SiGe heterostructures.

We report a notably low level of average charge noise of $\sim 0.5\ \mu eV/\sqrt{Hz}$ at 1 Hz and $\sqrt{S} = 46.5\ \mu eV/\sqrt{Hz}$ at 1 mHz.

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12. Observation of multi-channel transport assisted by excited energy level in a closed InAs-Al hybrid island Coulomb blockade regime

Junze Zhang1*, Jiyin Wang1, Zhihai Liu1, and Hongqi Xu1
1 Beijing Academy of Quantum Information Sciences, Beijing 100193, China
*zhangjz@baqis.ac.cn

Superconducting-semiconductor hybrid systems play a key role in quantum devices, which can also be a promising platform for realizing Kitaev chain or Majorana bound states [1–4]. This hybrid structure inherently processes a unique competition between charging energy and induced gap, which can be finely tuned by electric and magnetic fields [3,5,6]. To date, all these hybrid devices are been driving to a strong coupling, as Andreev bond states can emerge when superconductivity dominate the Coulomb blockade spectrum [7,8]. So far, there have been rare reports on the transition in the weak coupling regime, where quasiparticle exhibit a 2e charge quantisation, a feature can enhance the comprehensiveness on transition characteristic of superconductor-semicondcutor hybrid island gradually. To fill the gap, we investigate the interaction between superconductor and semiconductor under different coupling strength via three terminal devices with island of different length fabricated using indium-arsenide nanowire with epitaxial aluinium shell. We observed a multi channel transition assisted by excited energy level in closed regime which highlights the importance of hybrid systems coupling interation.

Devices fabricated with island length ranging from 300 nm to 3 μm, which give us an alternative ratio of charging energy to induced gap, since the plunger gate can only tune charging energy of the island slightly. Using finte-bias Coulomb blockade spectroscopy, we extracted charging energy of island in closed regime by applied global back gate (Vbg) and the conpensated plunger gate (Vp), which can be used to tune both charge on the island, as well as charge density of semiconductor. A finte-bias spectrum of 3 um long device, measured in a weak coupling regime, shown a 2e transition of dimond shape. Above the edge, another differential conductance peak is also observed, indicating a multi-channel transition behavior assisted by excited energy level.

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13. Theory of superconducting proximity effect in hole-based hybrid semiconductor-superconductor devices

D. Michel Pino[1*], Rubén Seoane Souto[1], María José Calderón[1], Ramón Aguado[1], and José Carlos Abadillo-Uriel[1]

1. Instituto de Ciencia de Materiales de Madrid (ICMM), Consejo Superior de Investigaciones Científicas (CSIC), Sor Juana Inés de la Cruz 3, 28049 Madrid, Spain

*dmichel.pino@csic.es

Hybrid superconductor-semiconductor systems have received a great deal of attention in the last few years because of their potential for quantum engineering, including novel qubits and topological devices. The proximity effect, the process by which the semiconductor inherits superconducting correlations, is an essential physical mechanism of such hybrids. Recent experiments have demonstrated the proximity effect in hole-based semiconductors, but, in contrast to electrons, the precise mechanism by which the hole bands acquire superconducting correlations remains an open question. In addition, hole spins exhibit a complex strong spin-orbit interaction, with largely anisotropic responses to electric and magnetic fields, further motivating the importance of understanding the interplay between such effects and the proximity effect. In this work, we analyze this physics with focus on germanium-based two-dimensional gases. Specifically, we develop an effective theory supported by full numerics, allowing us to extract various analytical expressions and predict different types of superconducting correlations including non-standard forms of singlet and triplet pairing mechanisms with non-trivial momentum dependence; as well as different Zeeman and Rashba spin–orbit contributions. This, together with their precise dependence on electric and magnetic fields, allows us to make specific experimental predictions, including the emergence of f-type superconductivity, Bogoliubov Fermi surfaces, and gapless regimes caused by large in-plane magnetic fields.

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14. Survival and Detection of Symmetry-Protected Topology in Loop Quenches

Nicolo Forcellini[1], Miklos Horvath[1*], and Panagiotis Kotetes[1]
1. Beijing Academy of Quantum Information Sciences, Beijing, China
*mikloshorvath@baqis.ac.cn

We bring forward a novel dynamical protocol, that we term loop quench, which is particularly designed for the study of symmetry-protected topological phases of matter [1]. Specifically, a loop quench allows for the inference of equilibrium topological invariants by means of measurable dynamical quantities. In this work, we focus on topological phases protected by a chiral symmetry, and introduce the Loschmidt chirality amplitude as a key observable which encodes the topological information of the equilibrium system. We exemplify our approach for the class of one-dimensional two-band insulators with chiral symmetry, for which we analytically establish the link between the Loschmidt chirality amplitude and the topological invariant. We further propose a pump-probe measurement scheme which involves two identically prepared chiral-symmetric insulators, with only one of them being subject to the loop quench. We reveal how such a setup enables the direct extraction of the amplitude in question. Our protocol not only uncovers a direct dynamical signature of the underlying symmetry-protected topology but, most importantly, it also serves as a general diagnostic framework that can be extended to other types of topological phases and dimensionalities.

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15. Optimal Control for Open Quantum Systems in Circuit Quantum Electrodynamics

Mo Zhou

Shanghai University

We propose a quantum optimal control framework based on the Pontryagin Maximum Principle to design energy- and time-efficient pulses for open quantum systems. By formulating the Langevin equation of a dissipative LC circuit as a linear control problem, we derive optimized pulses with exponential reduction in energy cost. When applied to a resonator dispersively coupled to a qubit, these optimized pulses achieve an excellent signal-to-noise ratio comparable to longitudinal coupling schemes across varying critical photon numbers. Our results provide a significant step toward efficient control in dissipative open systems and improve qubit readout in circuit quantum electrodynamics.

16. Green Function Invariants for Floquet Topological Superconductivity Induced by Proximity Effects

Mohamed Assili* and Panagiotis Kotetes
Beijing Academy of Quantum Information Sciences, Beijing 100193, China
*Email: assili@baqis.ac.cn

We bring forward a Green function approach for the prediction of Floquet topological phases in driven superconductor-semiconductor hybrids. Although it is common to treat the superconducting component as a mere Cooper-pair reservoir, it was recently pointed out that such an approximation breaks down in the presence of driving, due to the emergence of level broadening [1].

Here, we go beyond these recent works and prescribe how to construct the Floquet topological invariants for such driven hybrids. Specifically, we propose to first obtain the midgap quasi-energy spectra by including the hermitian part of the semiconductor's self-energy and, subsequently, read out the respective level broadenings by projecting the anti-hermitian part of the self-energy onto the quasi-energy eigenvectors [2].

We exemplify our approach for a Rashba nanowire coupled to a superconductor and a time-dependent Zeeman field. Using our method, we obtain the Floquet band structure, the respective level broadenings, and the topological invariants. Our analysis reinforces the need to properly account for the self-energy and corroborates that broadening effects can hinder the observation of the Floquet topological phases and especially of those harboring Majorana π modes.

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17. Zero-field vortex-Majorana composite excitations pinned by magnetic islands

Panagiotis Kotetes[1*] and Brian M. Andersen[2]
1. Beijing Academy of Quantum Information Sciences, Beijing 100193, China
2. Niels Bohr Institute, University of Copenhagen, DK-2200 Copenhagen, Denmark
*kotetes@baqis.ac.cn

We propose a route for pinning zero-field superconducting vortices in systems which are exchange-coupled to magnetic islands and feature Rashba spin-orbit coupling [1]. We consider islands with sizes which greatly exceed those of the vortex cores and possess out-of-plane magnetic moments. A crucial ingredient of our approach is that it considers superconductors which are governed by magnetic correlations without, however, exhibiting long range magnetic order. The arising total magnetization is inhomogeneous and its gradients generate a nonzero vorticity in the superconducting phase. Vortices become energetically stable due to the energy reduction brought about from the generation of electronic magnetization. Using our developed framework, we make concrete predictions for the emergence of zero-field vortices and Majorana zero modes in superconducting topological insulator surfaces and planar Rashba superconductors. Our theory uncovers a nonstandard path for trapping composite vortex-Majorana excitations in systems which appear to be within experimental reach.

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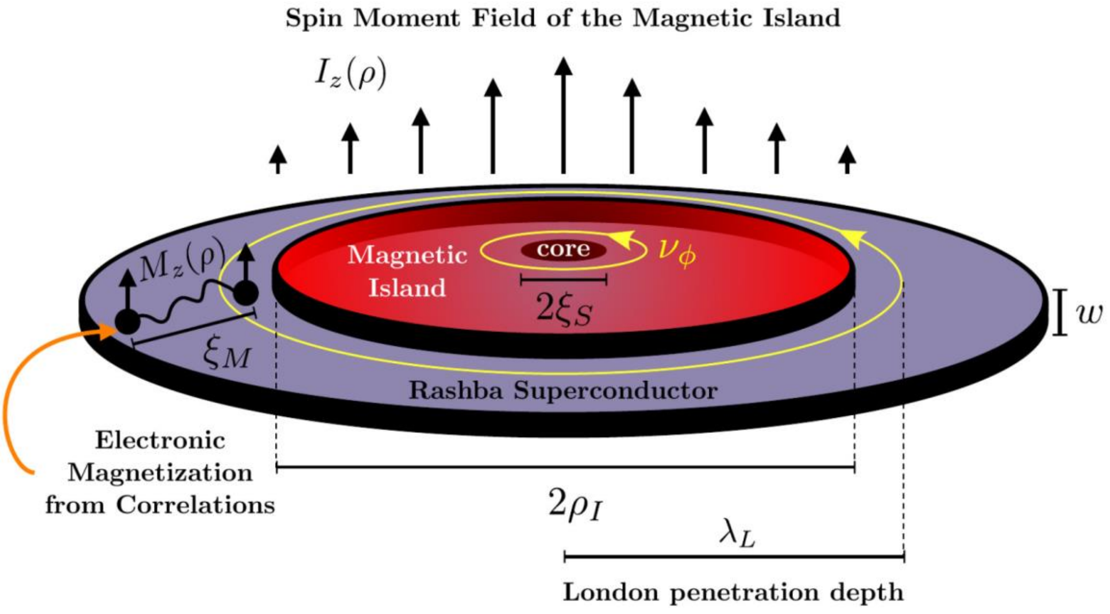

18. Quantum Computing with Topological Andreev Zero Modes

Thomas Lane[1*] and Panagiotis Kotetes[1]
1. Beijing Academy of Quantum Information Sciences, Beijing, China
*thomaslane@baqis.ac.cn

Topological quantum computing is a prime candidate for implementing fault-tolerant computing architectures due to its intrinsic robustness against noise and decoherence. This resilience stems from topological qubits being encoded non-locally, most commonly by employing non-abelian anyons such as Majorana zero modes [1]. However, the unequivocal experimental demonstration of Majoranas has proven to be a significant obstacle, thus making alternative methods for encoding topological qubits a pressing issue. In this work, we explore a novel design for a qubit which instead utilises topologically-protected Andreev zero modes bound to zero-dimensional defects. We demonstrate how these Andreev modes can arise in certain superconducting systems and are simultaneously invariant under the action of time-reversal and spin-rotations, at least about a single spin axis. Under these symmetry conditions, these superconductors belong to symmetry class AIII, possessing a chiral symmetry which also sets the fractionalised character of the arising Andreev zero modes.

As a concrete implementation of our proposal, we investigate a realisation of these modes in terms of a vortex-pinning mechanism [2]. Here, vortices trapping Andreev zero modes are introduced via a two-dimensional vector field spanned by energy gaps characterising the superconducting and normal-state phases. In addition to providing a proof of principle for the existence of such zero modes, we further analyse their fractionalised degrees of freedom and explore the prospect of employing these modes to implement fusion and braiding, which are central concepts in the development of topological quantum computing. This work has direct application to devices featuring proximity-induced superconductivity, with such hybrid systems expected combining the stability inherent to topological qubits with the well-established tunability associated with superconducting quantum circuits.

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19. Quantum-dot-based Kitaev chains with only local superconducting proximity effect

W. Samuelson, J. D

The possibility of engineering a Kitaev chain in quantum dots coupled via superconductors has recently emerged as a promising path toward topological superconductivity. I will discuss how some of the experimental hurdles on this path can be avoided by using only local proximity effect on each quantum dot in a geometry resembling a two-dot version of the proposal in Ref. [1]. There is no need for narrow superconducting couplers, additional Andreev bound states, or spatially varying magnetic fields; it suffices with spin-orbit interaction and a constant magnetic field, in combination with control of the superconducting phase to tune the relative strengths of elastic cotunneling and an effective crossed-Andreev-reflection-like process generated by higher-order tunneling. We use a realistic spinful, interacting model and show that high-quality Majorana bound states can be generated already in a double quantum dot [2]. I will also discuss the scaling properties of the Majoranas when the system is extended beyond two dots [3], as well as our recent developments of a fundamental framework for understanding Majoranas in interacting systems [4].

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20. Semiconductor Spin-Qubit Arrays for Axion Dark Matter and Weak-Field Detection

Xiangjun Tan[1*] and Zhanning Wang[2]

1. Department of Physics and Astronomy, University College London, WC1E 6BT London, United Kingdom

2. Instituto de Ciencia de Materiales de Madrid, 28049 Madrid, Spain

*xiangjun.tan.25@ucl.ac.uk

Axions and axion-like particles are compelling dark-matter candidates whose derivative couplings to fermion spins generate an oscillatory, spin-dependent effective field, often referred to as the axion wind. This talk explores semiconductor quantum-dot spin qubits as frequency-resolved quantum sensors for axion-induced spin dynamics and, more broadly, as a platform for weak-field detection at the nanoscale. By mapping the axion–spin interaction or other weak effective-field perturbations onto controlled phase accumulation in coherent spin-qubit protocols, semiconductor devices provide a tunable architecture in which coherence time, control bandwidth, sensor filter functions, and readout fidelity can be engineered for narrowband sensing. I will discuss how spectral engineering of spin-qubit control sequences can enhance sensitivity within targeted axion-mass windows while suppressing charge noise, magnetic noise, and control-induced backgrounds. Emphasis will be placed on realistic noise spectra, quantum-control filter functions, weak field sensitivity limits, and the resulting coupling reach. Beyond sensitivity optimization, I will show how the motion of the terrestrial laboratory through the Galactic dark-matter halo produces characteristic sidereal and annual modulation signatures, leading to structured sideband responses that provide a robust discriminator against stationary instrumental backgrounds. Finally, I will outline prospects for hybrid electronic–nuclear spin architectures, where long-lived nuclear coherence can be combined with fast electronic-spin initialization and readout through hyperfine-mediated transduction, offering a scalable and CMOS-compatible route toward chip-integrated weak field sensing, axion searches, and broader quantum-enabled dark-matter detection.

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21. Microwave Response of the Superconducting Diode Effect in Proximitized Bilayer Graphene Interferometers

Shili Yan[1*], Rubén Seoane Souto[2], and H. Q. Xu[1,3*]
[1] *Beijing Academy of Quantum Information Sciences, Beijing 100193, China*
[2] *Instituto de Ciencia de Materiales de Madrid (ICMM), 28049 Madrid, Spain*
[3] *Beijing Key Laboratory of Quantum Devices, Peking University, Beijing 100871, China*
*yansl@baqis.ac.cn; hqxu@pku.edu.cn

The superconducting diode effect (SDE), i.e., nonreciprocal dissipationless current transport in semiconductor-based superconducting junction devices, exhibits broad tunability with experimental parameters and holds promise for both fundamental physics studies and low-power superconducting electronic applications. Recent theoretical work has predicted a pronounced frequency dependence of the SDE in superconducting junction devices under microwave irradiation, showing, e.g., distinct tuning behaviors as a function of microwave power in slow- and fast-driving limits[1]. Experimental studies to date have mainly been limited to the slow-driving regime, where unidirectional superconductivity, i.e., the ideal SDE, can be achieved. Such an ideal SDE has been observed in a semiconductor nanowire Josephson junction under increasing microwave irradiation power [2].

In this work, we investigate the microwave response of the SDE in superconducting quantum interference devices (SQUIDs) across a broad range of driving frequencies, spanning experimentally from the slow- to the crossover-driving regimes and further extending into the fast-driving regime through simulations. Each SQUID studied consists of two Bernal-stacked bilayer graphene–Ti/Al Josephson junctions. At low frequency (1.2 GHz), we observe an ideal SDE tuned by microwave power, consistent with theoretical predictions in the slow-driving limit. As the frequency increases away from the slow-driving regime, complex and diverse tuning behaviors emerge. Specifically, for frequencies of 9.2 GHz and above, the diode efficiency reverses sign with increasing microwave power. Theoretical simulations based on the current–phase relations (CPRs) extracted from fits to the high-frequency experimental data reproduce the main features of the microwave tuning of the SDE at all experimentally investigated frequencies and further provide guidance for the tuning behavior toward fast-driving regime. Our findings provide new insights into the dynamics of superconducting junctions under microwave irradiation.

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22. One-dimensional quantum dot array integrated with charge sensors in a semiconductor nanowire

Yi Luo[1,2], Xiao-Fei Liu[1], Dong Pan[3], Jianhua Zhao[3], Ji-Yin Wang[1,*], and H. Q. Xu[1,2,*]
1. Beijing Academy of Quantum Information Sciences, Beijing 100193, China
2. Beijing Key Laboratory of Quantum Devices, Key Laboratory for the Physics and Chemistry of Nanodevices, and School of Electronics, Peking University, Beijing 100871, China
3. State Key Laboratory of Superlattices and Microstructures, Institute of Semiconductors, Chinese Academy of Sciences, P.O. Box 912, Beijing 100083, China
*H. Q. Xu, E-mail: hqxu@pku.edu.cn; Ji-Yin Wang, E-mail: wang_jy@baqis.ac.cn

We report an experimental study of a 1D quintuple-quantum dot array integrated with two charge sensors in an InAs nanowire (Fig.1)[1]. The energy level of each dot in the array can be controlled individually using virtual gates. After that, four dots in the array are selected to form two double quantum dots, and ultrastrong inter-double-dot interaction is obtained. In addition, we have further employed radio-frequency (RF) measurements and manipulations on quantum dots made of a semiconductor nanowire. The plunger gate electrodes of the double dot are connected to impedance-matched RF lines with cryogenic bias tees, where the drive microwave is pulse modulation (PM) by a Lock-in amplifier. Current through the device is amplified and returned to the Lock-in amplifier for demodulation. The electric dipole spin resonance (EDSR) pulse sequence is applied to the plunger gates after the double dot is tuned to spin blockade state. When the drive microwave frequency matches the Larmor frequency, blockade is lifted and current increases. The EDSR line about magnetic filed and drive frequency is observed experimentally. The highly controllable one-dimensional quantum dot array achieved in the work is expected to be valuable for employing semiconductor nanowires to construct advanced quantum hardware in the future.

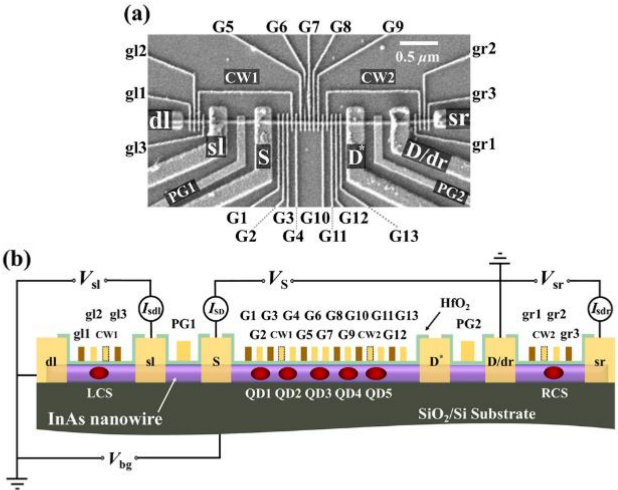

Fig. 1: (a) Scanning electron microscope (SEM) image of the device comprising a 1D quintuple-quantum dot array and charge sensors. (b) Cross-sectional schematic view and measurement setup.

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23. A microscopic description of singlet–triplet hole qubits in double dots

Yongtao Li, Zhanning Wang, Rubén Seoane Souto, José Carlos Abadillo-Uriel*
Instituto de Ciencia de Materiales de Madrid (ICMM), Consejo Superior de Investigaciones Científicas (CSIC)
*jc.abadillo.uriel@csic.es

Hole spin qubits in semiconductor quantum dots offer strong intrinsic spin–orbit coupling (SOC) and reduced hyperfine sensitivity, making them promising candidates for fast, all-electrical qubit control. In singlet–triplet (ST) qubits hosted in lateral double quantum dots (DQDs), the interplay between SOC, anisotropic g-factors, and magnetic fields plays a central role in shaping the qubit's energy structure and noise sensitivity.[1]

In this work, we develop a microscopic model of a hole ST qubit in a lateral DQD that incorporates Rashba SOC and anisotropic, kinetic-dependent g-factors. Central to our results is the emergence of spin-dependent magneto-tunneling terms, which arise from the interplay between the kinetic interactions between heavy-hole and light-hole and kinetic-dependent Zeeman terms. These corrections modify interdot tunneling in a spin-selective way, reshaping the exchange interaction, restoring the Pauli spin blockade (PSB), and reducing leakage current in ways not captured by simpler models..

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24. Broad nonlocal spectrum in the Pb-InSb hybrid three terminals for potential realization of Kitaev chains

Guoan Li[1,5], Xiaofan Shi[1,5], Yuxiao Song[1,5], Ruixuan Zhang[1,5], Marco Rossi[2], Ghada Badawy[2], Zhiyuan Zhang[1,5], Anqi Wang[1], Xingchen Guo[1,5], Xiao Deng[1,5], Xiao Chen[1,5], Liangqian Xu[1,5], Bingbing Tong[1], Peiling Li[1], Xiaohui Song[1], Zhaozheng Lyu[1], Guangtong Liu[1,6], Fanming Qu[1,5,6], Michał P. Nowak[3], Paweł Wójcik[4], Ziwei Dou[1*], Erik P. A. M. Bakkers[2*], Li Lu[1,5,6*], and Jie Shen[1*]

1. Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China.

2. Department of Applied Physics, Eindhoven University of Technology, 5700 MB Eindhoven, The Netherlands.

3. AGH University of Krakow, Academic Centre for Materials and Nanotechnology, al. A. Mickiewicza 30, 30-059 Krakow, Poland.

4. AGH University of Krakow, Faculty of Physics and Applied Computer Science, al. A. Mickiewicza 30, 30-059 Krakow, Poland.

5. School of Physical Sciences, University of Chinese Academy of Sciences, Beijing 100049, China.

6. Hefei National Laboratory, Hefei 230088, China.

*ziweidou@iphy.ac.cn
*e.p.a.m.bakkers@tue.nl
*lilu@iphy.ac.cn
*shenjie@iphy.ac.cn

Hybrid superconductor–semiconductor nanowires remain one of the foremost platforms for engineering Majorana zero modes towards topological qubits, especially with the rapid development of Kitaev chains. In contrast to the widely used aluminum (Al), lead (Pb) offers a much larger superconducting gap and a high critical-temperature. Here we present the first three-terminal Pb-based devices and non-local differential-conductance measurement, resolving an extraordinarily large, hard induced gap. Inside, the Andreev bound states (ABSs) undergo singlet-doublet transitions. Moreover, we achieve gate-controlled resonating sign reversals of the non-local conductance, identifying three quantum-dot (QD) configurations (single-, double-, and series- resonances). Finally, the inter-site coupling between ABSs and QDs can be modulated from weak to strong, desirable for Kitaev chains. Crucially, the non-local signatures protected by the substantially larger gap could persist up to ~1 K far above the operating-temperature of Al's, thereby widening the parameter space greatly and underscoring the suitability of Pb-based devices for implementing high temperature Kitaev chains.

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25. Chiral quantum acoustics with semiconductor hole spin qubits --SSTQD2026

Zhanning Wang[1*], Yongtao Li[1], and José C. Abadillo-Uriel [2]
1. Instituto de Ciencia de Materiales de Madrid (ICMM - CSIC)
*z.w@csic.es

Semiconductor hole spins combine strong spin-orbit coupling with scalable gate-defined architectures, but their predominantly electric control exposes the qubit frequency to the same charge noise channels used for manipulation [1]. Here we develop a theory of surface acoustic wave control and coupling of hole spin qubits in strained Ge quantum wells. Treating a Rayleigh surface acoustic wave as both a classical drive and a quantized itinerant phonon, we derive the Bir-Pikus spin-phonon interaction and project its finite wave-vector strain tensor onto realistic spin-orbit mixed hole states.

The resulting coupling contains transverse and longitudinal components within a single microscopic mechanism, enabling acoustic Rabi driving, qubit-frequency modulation, and phonon-mediated interactions.

We show that the elliptic polarization of the Rayleigh mode produces a direction-dependent spin response: the acoustic angular momentum is locked to propagation direction and interferes with the anisotropic hole-spin matrix elements to generate chiral driving and emission. This directional, tensorial coupling can be tuned by electric field, magnetic field orientation, dot geometry, and acoustic polarization. Our results extend surface acoustic waves as a coherent quantum acoustic interface for semiconductor spin qubits, providing a route toward chiral spin control, dynamical sweet spots, itinerant-phonon entanglement, and programmable acoustic spin arrays.

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26. Enhancement of charge stability in Ge quantum devices through interface treatment

Zhengqing Wei[1*], Ding-Ming Huang[1], Jian-Jun Zhang[2], Ji-Yin Wang[2] and H. Q. Xu[1,3]
1. Beijing Academy of Quantum Information Sciences, Beijing 100193, China
2. Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China
3. Beijing Key Laboratory of Quantum Devices, Peking University, Beijing 100871, China
*weizq@baqis.ac.cn

Two-dimensional hole gases (2DHGs) in Ge/SiGe heterostructures have emerged as a particularly promising platform for high-performance spin qubit processors, owing to their exceptional intrinsic properties: strong and gate-tunable spin-orbit coupling, all-electrical control, low nuclear spin noise, absence of valley degeneracy, and inherent compatibility with advanced semiconductor manufacturing.[1] Currently, the trapped states at oxide-SiGe interfaces represent a critical bottlenecks, limiting the qubit performance via elevating charge noise and deteriorating gate stability. Thus, mitigating the interface state issue is a critical prerequisite for improving the performance of spin qubit processors.

In this work, we have adopted surface treatment onto Ge/SiGe heterostructures to diminish the interface trapped states. Based on Ge/SiGe heterostructures grown by molecular beam epitaxy (MBE), we develop low-damage lithography and plasma etching processes, and combine low-temperature ozone surface passivation with atomic layer deposition (ALD) of high-κ gate dielectrics to effectively reduce interfacial charge trapping and enhance device stability. [2] Key transport parameters including carrier density, mobility, and threshold voltage are extracted using a Physical Property Measurement System (PPMS), and comprehensive Landau fan diagrams are constructed. Our experimental results demonstrate that low-temperature ozone oxidation effectively passivates interfacial dangling bonds, substantially reduces interface state density, suppresses gate threshold voltage drift, improves the initial plateau region, attenuates remote scattering, and consequently prolongs the quantum scattering time. Our work provides critical process support for the fabrication of high-fidelity Ge-based hole spin qubits and lays a solid foundation for future high-precision spin manipulation experiments.

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27. Majorana-Based Parity Qubit Processor in Hybrid Quantum Dot Arrays

Zhi-Hai Liu[1*], Jiang Zhang[1], Guilu Long[1,2], and Hongqi Xu[1,3]

1. *Beijing Academy of Quantum Information Sciences, Beijing 100193, China*
2. *State Key Laboratory of Low-Dimensional Quantum Physics and Department of Physics, Tsinghua University, Beijing 100084, China*
3. *Beijing Key Laboratory of Quantum Devices, Peking University, Beijing 100871, China*

*liuzh@baqis.ac.cn

Semiconductor-superconductor hybrid nanostructures have attracted intensive attention for hosting Majorana fermions. Elastic cotunneling and crossed Andreev reflection across quantum dots (QDs) interconnected by superconducting hybrid segments enable the simulation of minimal Kitaev chains, giving rise to authentic poor-man Majorana bound states (PMMs). A parity qubit is constructed using two pairs of PMMs localized in series-coupled chains. Leveraging the tunability of interchain superconducting phase difference and magnetic-field induced Zeeman spin splitting (a prerequisite for generating PMMs), we demonstrate geometric manipulation of the parity qubit, based on which universal single-qubit gates can be implemented. Owing to the geometric feature of the control scheme, the resultant qubit gates exhibit strong robustness against noise and fluctuations. Furthermore, the scalable QD array architecture affords the possibility to engineer exchange coupling between the parity and spin qubits, under strong intradot Coulomb repulsion. By virtue of fast electric-dipole spin resonance for spin qubits, we also show high-fidelity parity-qubit state transfer and attain reliable readout via tailoring driving pulse sequences.