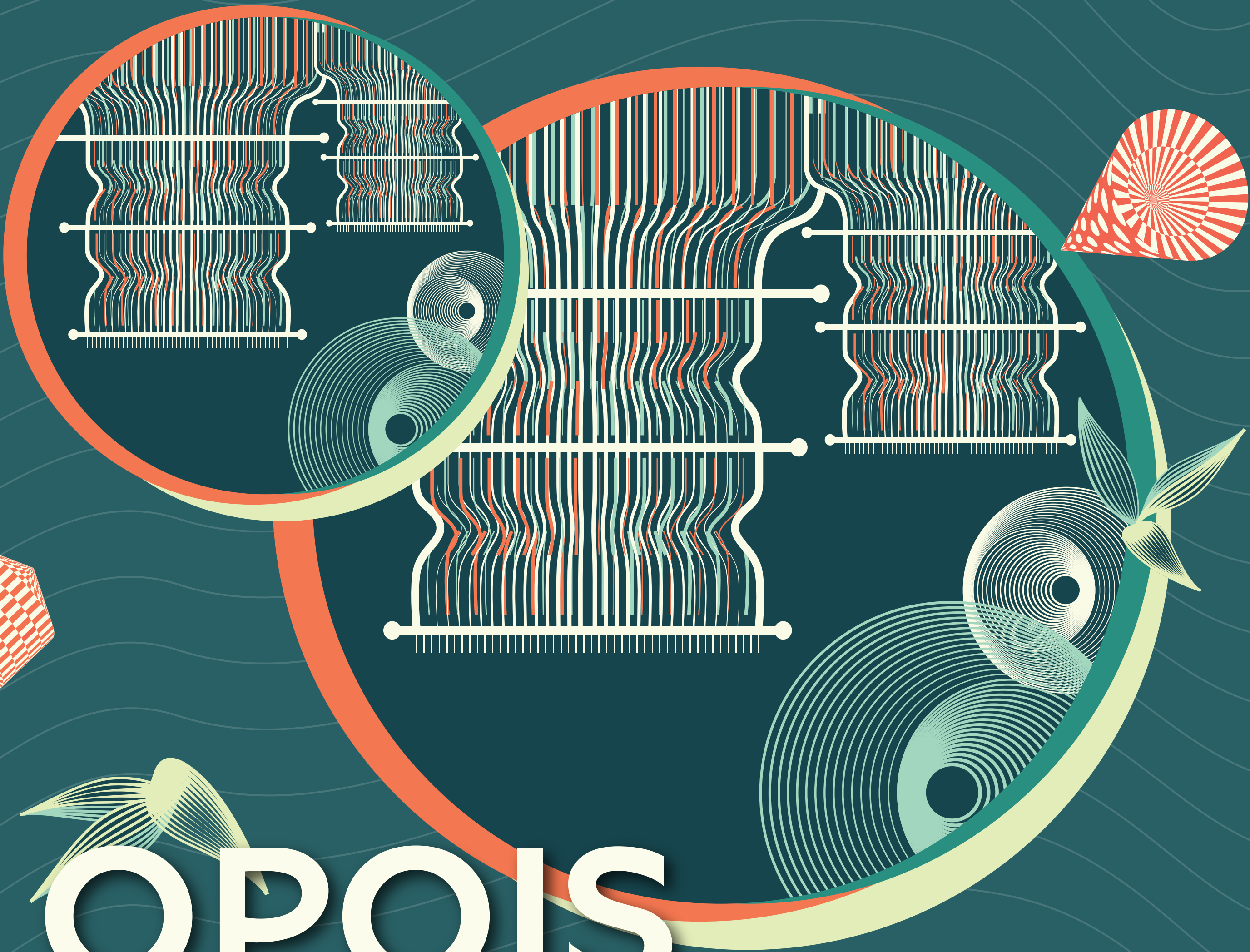
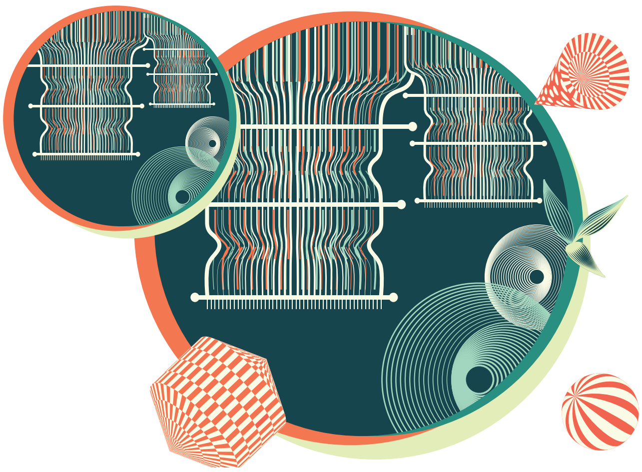


QPQIS 2021

International Symposium on Quantum Physics and Quantum Information Sciences

Progress of Fundamental Research in Quantum Computation

北京量子信息科学研究院
Beijing Academy of Quantum Information Sciences



ABOUT QPQIS2021

Welcome to The 3rd International Symposium on Quantum Physics and Quantum Information Sciences (QPQIS2021), hosted by Beijing Academy of Quantum Information Sciences (BAQIS) on 2nd-3rd December 2021 (Beijing Time).

QPQIS2021 will focus on "Progress of Fundamental Research in Quantum Computation". Quantum computation is at the core of quantum science and technology, and expected to provide revolutionary solutions for many real-world issues which are too complex to be solved by classical computing. Quantum computing based on different platforms has made tremendous progress in recent years, indicating a promising future in this field. The main topics of QPQIS2021 include: improvements of materials and fabrication processes of quantum computing systems, control systems, qubit and gate manipulations, error correction methods, architectures, quantum algorithms, software stacks, etc., with regard to major realization schemes of quantum computing such as superconducting, trapped-ion, semiconductor, photonic, spin, topological qubits.

QPQIS2021 brings together 19 world-leading theoretical and experimental research scientists as invited speakers to share their most recent progress.

QPQIS2021 also features a poster session, which will allow an extended group of scientists, especially young scholars working at the forefront of quantum computing research to share their latest results.

BEIJING ACADEMY OF QUANTUM INFORMATION SCIENCES

Beijing Academy of Quantum Information Sciences (BAQIS) was established on December 24, 2017. Partnering with top research institutions such as Tsinghua University, Peking University, and Chinese Academy of Sciences, etc., BAQIS is taking advantages of the most favorable strength for quantum information research in Beijing.

BAQIS aims at developing the world first class innovative research institution, standing at the forefront of quantum physics and quantum information sciences research. It runs with a management model of international standard, integrates strength resources from all partnering institutions, vigorously introduces global top talents to form the research teams. The research teams are to be led by scientists with potential for strategic scientific and technological innovations, and supported by highly expertized engineers, and provided with world class experimental platforms. It strives to achieve world class results in the fundamental research of quantum state of matter, quantum communication and computation, quantum materials and devices, quantum precision measurement. You are welcome to scan the following QR code to browse BAQIS website or follow our WeChat official account.

QR Code of BAQIS Website

QR Code of BAQIS Wechat Official Account

ORGANIZING COMMITTEE

CHAIR:

Qi-Kun Xue (BAQIS / SUSTech), Tao Xiang (BAQIS / IOPCAS).

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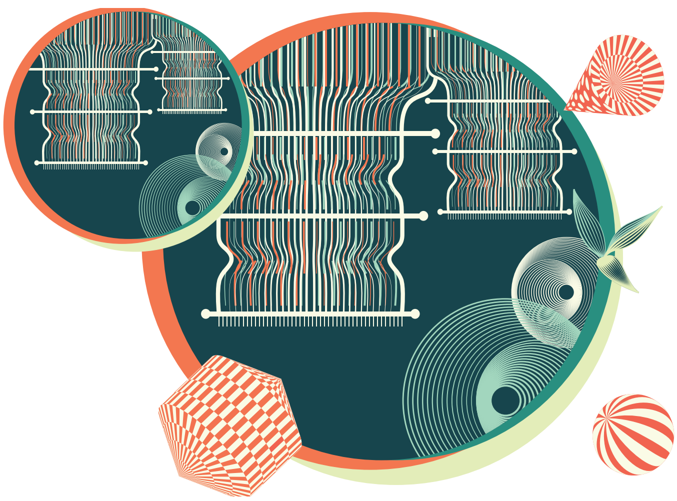
Hong-Qi Xu (Peking Univ. / BAQIS)
Huai-Bin Zhuang (BAQIS).



BEIJING ACADEMY OF QUANTUM INFORMATION SCIENCES

PROGRAM

Day 1 / December 2

OPENING CEREMONY (Moderator: *Huai-Bin Zhuang* | BAQIS)

08:50-09:00 • **Opening Speech**
Qi-Kun Xue | BAQIS / SUSTech

SESSION 1 (Session Chair: *Gui-Lu Long* | Tsinghua Univ. / BAQIS)

09:00-09:45 • **Quantum Control of Spins in Solids and Its Applications**
Jiangfeng Du | University of Science and Technology of China

09:45-10:30 • **On Quantum Computational Supremacy**
Scott Aaronson | University of Texas at Austin, USA

10:30-10:45 • **Online Group Photo / Break**

10:45-11:30 • **High-fidelity gates in a coupled superconducting-qubit system**
Haifeng Yu | BAQIS

11:30-12:15 • **Superconducting quantum computing**
Xiaobo Zhu | USTC Shanghai Institute for Advanced Studies

12:15-14:00 • **Lunch / Poster Session**

SESSION 2 (Session Chair: *Ke He* | Tsinghua Univ. / BAQIS)

14:00-14:45 • **Quantum computation of molecular structure using data from challenging-to-classically-simulate nuclear magnetic resonance experiments**
Tom O'Brien | Google, USA

14:45-15:30 • **Si platform for implementing spin-based quantum computing**
Seigo Tarucha | RIKEN, Japan

15:30-16:15 • **Progress on trapped ion quantum computing and networking**
Luming Duan | Tsinghua University

16:15-16:30 • **Break**

16:30-17:15 • **Quantum computing with trapped ions**
Ferdinand Shimidt Kaler | Johannes Gutenberg – Universität Mainz, Germany

17:15-18:00 • **Experimental simulation of PT-symmetric quantum system using single trapped ion**
Wei Zhang | Renmin University of China

18:00-18:45 • **The next step in Quantum Computing: From NISQ to PISQ**
Koen Bertels | KU Leuven / QBee.eu, Belgium

19:30-20:30 • **Online Poster Discussion**

Day 2 / December 3

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

09:00-09:45 **Recent Progress in Coherent Ising Machines**
Yoshihisa Yamamoto | NTT Research / Stanford University, USA

09:45-10:30 **Photonic quantum computational advantage**
Chaoyang Lu | USTC Shanghai Institute for Advanced Studies

10:30-10:45 **Break**

10:45-11:30 **Developing technologies towards an error-corrected quantum computer**
Yu Chen | Google, USA

11:30-12:15 **Semiconductor nanolayers: A new platform for developments of quantum and topological devices**
Hongqi Xu | Peking University / BAQIS

12:15-14:00 **Lunch / Poster Session**

SESSION 4 (Session Chair: *Tian Pei* | BAQIS)

14:00-14:45 **Coherent errors in quantum error correction and fault-tolerant quantum computation**
Dong Liu | Tsinghua University / BAQIS

14:45-15:30 **Perspectives on single atom based scalable silicon quantum computing**
Yu He | Southern University of Science and Technology

15:30-15:45 **Break**

15:45-16:30 **Deconfinement of Majorana vortex modes in a topological superconductor**
Carlo Beenakker | Leiden University, Netherlands

16:30-17:15 **Quantum Computation and Simulation -- Spins Inside**
Lieven Vandersypen | QuTech / Delft University, Netherlands

17:15-18:00 **Superconducting quantum computing chip with a vertically accessed two-dimensional array of qubits**
Yasunobu Nakamura | University of Tokyo, Japan

CLOSING CEREMONY (Moderator: *Huai-Bin Zhuang* | BAQIS)

18:00-18:05 **Closing Remark**
Hong-Qi Xu | Peking Univ. / BAQIS

18:05-18:15 **Announcement of Best Poster Awards**
Tao Xiang | BAQIS / IOPCAS

ABOUT THE SPEAKERS

Scott Aaronson

Scott Aaronson is David J. Bruton Centennial Professor of Computer Science at the University of Texas at Austin. He received his bachelor's from Cornell University and his PhD from UC Berkeley. Before coming to UT Austin, he spent nine years as a professor in Electrical Engineering and Computer Science at MIT. Aaronson's research in theoretical computer science has focused mainly on the capabilities and limits of quantum computers. His first book, Quantum Computing Since Democritus, was published in 2013 by Cambridge University Press. He's received the National Science Foundation’s Alan T. Waterman Award, the United States PECASE Award, the Tomassoni-Chisesi Prize in Physics, and the ACM Prize in Computing, and is a Fellow of the ACM.

ABOUT THE SPEAKERS

Carlo Beenakker

Carlo Beenakker studied physics at Leiden University (Ph.D. 1984). He worked at the Philips Research Laboratories before returning to Leiden in 1991 as professor of theoretical physics at the Lorentz Institute, a chair he holds to this date.

In 1987, while at Philips Research, Carlo Beenakker contributed to the discovery and explanation of conductance quantization in a quantum point contact, for which he shared the Royal Dutch Shell prize (1993). In Leiden he continued his research on quantum transport in nanostructures, honored with the Spinoza prize (1999), which is the highest scientific award in the Netherlands, the Physica prize (2003), and the AKZO Nobel Science Award (2006). His recent research is in the field of topological superconductivity, focusing on the ways in which Majorana fermions can be used for topological quantum computations, in close collaboration with the QuTech laboratory in Delft.

Carlo Beenakker has co-authored over 350 publications and is recognized by the Web of Science as a "Highly-cited Researcher". For his services to science and society he was elected member to the Royal Netherlands Academy of Arts and Sciences and knighted in the Order of the Dutch Lion.

ABOUT THE SPEAKERS

Koen Bertels

Koen Bertels' current scientific research focuses on quantum computing and on the definition and implementation of a scalable quantum micro- and system architecture. He was a professor at Delft University of Technology working on the quantum topics. He was instrumental in making the US-based Intel finance the company's initiative in quantum research in Delft. His group developed one of the first full stacks for a quantum computer. As he wanted to go beyond the physics challenges, he decided to change university and now he is full professor the university of Leuven in Belgium. He also created a company called QBee.com, with investments from Malaysia and Singapore. His work still involves specifying what the micro-architectural support is for the control of the quantum instructions and how the quantum accelerator is connected and integrated in a larger system design where classical logic is combined with quantum logic. The main approach focuses more on quantum accelerators and the full-stack definition that the QCA lab has defined and developed. In this context, the group defined many things such as the programming language, OpenQL, a generic implementation for the micro-architecture and the QBeeSim simulator platform to execute any quantum logic that can be defined.

ABOUT THE SPEAKERS

Tom O' Brien

Tom O'Brien is a research scientist at Google Quantum AI with a focus on developing new algorithms and finding new applications for quantum computers, and leading collaborations with industrial and academic partners in EMEA and APAC. Tom completed his undergraduate studies in Australia (University of Wollongong / University of Queensland), his masters at the Perimeter Institute in Waterloo, Canada, and his PhD (cum laude) at Leiden University. Before joining Quantum AI, Tom was a faculty member at Leiden University, where he was a founding member of the Applied Quantum Algorithms group and remains in a guest position.

ABOUT THE SPEAKERS

Yu Chen

Yu Chen leads the Hardware Metrology Team in Google Quantum AI Lab. He and his team are responsible for developing metrology tools to improve our quantum computing system performance. He earned his PhD in physics from the University of Minnesota and did postdoctoral research at the University of California, Santa Barbara. Since joining Google in 2014, Yu and his team have been working to build fundamental understandings to the technology stack. These span from optimizing component performance such as gate or readout to developing next-generation hardware, such as cryogenic systems, necessary to scale Google's quantum computing systems.

ABOUT THE SPEAKERS

Jiangfeng Du

Prof. Jiangfeng Du is a professor of University of Science and Technology of China (USTC) and the Academician of Chinese Academy of Sciences. He received his doctoral degree in USTC in 2000. Since the year 2004 he works as a professor and now he serves as vice president of USTC. Prof. Du developed a series of advanced spin quantum control methods to precisely manipulate spin quantum states as well as several kinds of advanced magnetic resonance spectrometers. Based on these, he made fruitful achievements by applying the spin quantum control technologies into information and metrology sciences. The major research results include prolonging the spin quantum coherence time by three orders against the realistic quantum noises and demonstrating the single-protein spin resonance spectroscopy under ambient conditions. Du was awarded the second prize of National Natural Science Award, The Outstanding Achievements in Natural Science by the Ministry of Education of China, The Huang Kun Award of Solid-state Physics and Semiconductor Physics from Chinese Physical Society, and The Award in Basic Science from Zhou GuangZhao Foundation.

ABOUT THE SPEAKERS

Luming Duan

Prof. Luming Duan received his bachelor (Ph. D) degree from USTC in1994 (1998). After appointments of assistant, associate, full professor and Fermi collegiate chair professor at the University of Michigan, he returned full time to China in 2018 and took the CC Yao Professor and the chair professorship in fundamental sciences at Tsinghua University. He received numerous awards, including Rao Ru-Tai fundamental optics prize, Huo Ying-Dong Prize, A. P. Sloan Fellowship, and was elected in 2009 to the APS fellowship.

Prof. Duan is a world expert on quantum computing and networking and has accomplished seminar works in the field of quantum information science. He proposed the well-known DLCZ scheme for quantum repeaters and modular network approach to quantum computing, laying an important foundation to scale up the sizes for quantum communication and computation. He published more than 200 paper in prestigious journals, including 2 in Rev. Mod. Phys., 8 in Nature, 3 in Science, and received more than 30,000 citations in Google scholar.

ABOUT THE SPEAKERS

Yu He

Dr. Yu He is from the Institute of Quantum Science and Engineering (IQSE), Southern University of Science and Technology, Shenzhen. Dr. Yu's main research field is quantum physics and quantum computation in semiconductor systems, including self-assembled quantum dots and silicon dopants. Currently, Dr. Yu is building a team to pursue frontier quantum computing techniques combined with fundamental physics in silicon quantum devices. In total, Dr. Yu has published 23 peer-reviewed top-tier papers (including 1 Nature, 2 Nature Nanotechnology, 2 Nature Photonics, 9 Physical Review Letters), with a total citation of 3200 and an h-index of 18. Dr. Yu was listed as one of the Innovators Under 35 in the China region by MIT Technology Review in 2020.

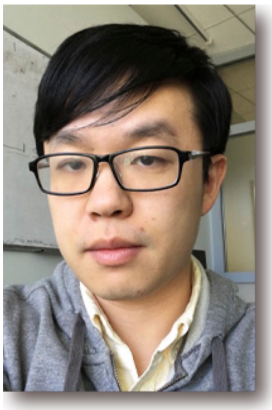
ABOUT THE SPEAKERS

Ferdinand Schmidt-Kaler

Ferdinand Schmidt-Kaler studies of physics at Univ. Bochum, Bonn, and München. Diploma with H. Walther and G. Rempe (1989), PhD with T. Hänsch at Max Planck Inst. for Quantum Optics, München (1992), Postdoc with S. Haroche at Ecole Normale Sup., Paris (until 1995), Assistant with R. Blatt and Assistant Professor at Univ. Innsbruck, Austria (until 2005), full Professor and head of Inst. for Quantum Information Processing at Univ. Ulm (until 2010), and since then full Professor and head of unit QUANTUM at Univ. Mainz. Main research fields include laser cooling and trapping of atoms and ions, high resolution spectroscopy, quantum information technologies with atoms, ions, electrons and solids. More than 200 publications with >18k citations.

ABOUT THE SPEAKERS

Dong Liu



Dr. Dong Liu is an associate professor at Tsinghua University and a research scientist at Beijing Academy of Quantum Information Sciences. He got his B.S. and PhD degrees at Peking University and Duke University, and worked as a postdoc researcher at Michigan State University and Microsoft Station Q. He joined Tsinghua University in 2018 as a faculty member. He became an adjunct scientist at BAQIS in 2020 and is leading a research group of quantum computer operating system. He mostly focused on the theory of quantum devices physics, quantum computer architecture, topological quantum computation, and non-equilibrium condensed matter physics.

ABOUT THE SPEAKERS

Chao-Yang Lu

Chao-Yang Lu obtained his PhD in Physics from the University of Cambridge in 2011. He is currently a Professor of Physics at USTC. His research interest includes quantum computation, quantum photonics, multi-particle entanglement, quantum teleportation, superconducting circuits, and atomic arrays. His work on quantum teleportation was selected as by Physics World as "Breakthrough of the Year 2015". He has been awarded as Fellow of Churchill College (2011), Hong Kong Qiu Shi Outstanding Young Scholars (2014), National Science Fund for Distinguished Young Scholars (2015), Nature's top ten "science star of China" (2016), OSA Fellow (2017), Fresnel Prize from the European Physical Society (2017), AAAS Newcomb Cleveland Prize (2018), Huangkun Prize from Chinese Physical Society (2019), Nishina Asian Award (2019), Xplorer Prize (2019), IUPAP-ICO Young Scientist Prize in Optics (2019), OSA Adolph Lomb Medal (2020), and Rolf Landauer and Charles H. Bennett Award in Quantum Computing (2021). He is the Chair of Quantum 2020 and has served as an editorial board member in international journals such as Quantum Science and Technology, PhotoniX, Advanced Photonics, Advanced Quantum Technology, Science Bulletin, and iScience.

ABOUT THE SPEAKERS

Yasunobu Nakamura

Yasunobu Nakamura started his research career at NEC Fundamental Research Laboratories in 1992, where he demonstrated the first coherent manipulation of a superconducting qubit in 1999 and met quantum information science. He spent a year as a Visiting Researcher in TU Delft from 2001 to 2002. Since 2012, he has been a Professor in Research Center for Advanced Science and Technology (RCAST) of the University of Tokyo. He has also been leading his research team in RIKEN since 2014. He is currently the Director of RIKEN Center for Quantum Computing (RQC) as well as the Project Leader of the MEXT Q-LEAP Flagship project on Superconducting Quantum Computing. His current research area covers superconducting quantum computing, microwave quantum optics and hybrid quantum systems.

ABOUT THE SPEAKERS

Seigo Tarucha

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 Basic Research Laboratories in 1978 and received the Ph. D degree from the University of Tokyo in 1986. In 1998 he moved to the University of Tokyo as a professor in the Physics Department and then to the Applied Physics Department in 2005. In April 2019 he retired from the University of Tokyo and moved to RIKEN Center for Emergent Matter Science (CEMS). He has been running a research group in CEMS since 2013 and also working as a CEMS deputy director since 2018. He has been concurrently serving as a research team leader for RIKEN Center for Quantum Computing since April 2020. He was a guest scientist in Max-Planck-Institute (Stuttgart) in 1986 and 1987 and in Delft University in 1995. He is currently working on spin-based quantum computing and topological quantum computing. 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, and Achievement award of Japan Applied Physics Society in 2018.

ABOUT THE SPEAKERS

Lieven Vandersypen

Prof. Dr. ir Lieven Vandersypen is Antoni van Leeuwenhoek professor in Quantum Nanoscience at Delft University of Technology and Scientific Director of QuTech, an advanced research centre for Quantum Computing and Quantum Internet. He received his PhD in Electrical Engineering from Stanford University for the first experiments in quantum computing. He is a pioneer in single-spin qubits in semiconductor quantum dots, for applications in quantum computing and quantum simulation. He received Starting, Synergy and Advanced grants of the European Research Council. He is a member of the Royal Holland Society of Sciences and Humanities (KHMW), received the IUPAP Young Scientist Prize for Semiconductor Physics and the Nicholas Kurti European Science Prize, as well as the Spinoza Prize, which is the highest scientific award in the Netherlands.

ABOUT THE SPEAKERS

Hongqi Xu

Hongqi Xu is Chair Professor at Peking University and Chief Scientist at Beijing Academy of Quantum Information Sciences. He received the Ph.D. degree in condensed matter physics from Lund University, Sweden, in 1991. From 1991 to 1993, he was Postdoctoral Fellow at Linköping University, Sweden. In 1993, he returned to Lund University, where he was employed as Research Associate in 1993-1995 and was appointed Assistant Professor in 1995-2001, Associate Professor in 2001-2003, and Full Professor in 2003-2014. He has been appointed Chair Professor at Peking University from 2010 and Director of Beijing Key laboratory of Quantum Devices from 2017. In early 2021, he has been appointed Chief Scientist and Director of Quantum Computation Division of Beijing Academy of Quantum Information Sciences. He is a Fellow of American Physical Society. He currently works on experimental and theoretical studies of electron transport in quantum structures, topological states of matter and Majorana fermions in the solid state, strong correlated systems, as well as semiconductor spin physics and spin qubits.

ABOUT THE SPEAKERS

Yoshihisa Yamamoto

Yoshihisa Yamamoto is the Director of PHI (Physics & Informatics) Laboratories, NTT Research, Inc. He received B.S. degree from Tokyo Institute of Technology and Ph.D. degree from the University of Tokyo in 1973 and 1978, respectively, and joined NTT Basic Research Laboratories in 1978. He became a Professor of Applied Physics and Electrical Engineering at Stanford University in 1992 and also a Professor at National Institute of Informatics (NII) in 2003. He is currently a Professor (emeritus) of Stanford University and NII. His past research areas are coherent communications, squeezed states, quantum non-demolition measurements, exciton-polariton BEC, single photon and spin-photon entanglement generation and mesoscopic transport noise. He has received many distinctions for his past work, including Carl Zeiss Award (1992), Nishina Memorial Prize (1992), IEEE/LEOS Quantum Electronics Award (2000), Medal with Purple Ribbon (2005), Hermann A. Haus Lecturer of MIT (2010), and Okawa Prize (2011). His current research interest focuses on quantum information processing, physics of quantum-to-classical transition and coherent Ising machines

ABOUT THE SPEAKERS

Haifeng Yu

Haifeng Yu is a research scientist in Beijing Academy of Quantum Information Sciences. His research directions are superconducting quantum computing and quantum simulation. His representative work includes preparing the first superconducting qubit in China and observing the coherent oscillation, by using the superconducting quantum chip to realize the simulation of a series of topological semi-metallic band structures, realizing the preparation of a long-lived superconducting qubit of up to 0.5 milliseconds and 99.54% high-fidelity two-qubit controlled-phase gate. He has published more than 40 scientific articles in related fields, and hosted four national/provincial-level projects. In 2019, he was enrolled in the National Hundreds and Thousands of Talents Project.

ABOUT THE SPEAKERS

Wei Zhang

Dr. Wei Zhang received his doctoral degree in School of Physics at Georgia Institute of Technology in 2006. After graduation, he worked as a Research Fellow in University of Michigan, and then joined Department of Physics at Renmin University of China in 2008. In 2014, Dr. Zhang was promoted to full professor. Dr. Zhang has been working in the field of atom, molecule and optic physics in the past few years, particularly focusing on quantum computation with trapped ion, as well quantum many-body effects and exotic quantum states in various experimental systems and important theoretical models.

ABOUT THE SPEAKERS

Xiaobo Zhu

Prof. Xiaobo Zhu received his PhD in condensed matter physics at Institute of Physics, Chinese Academy of Sciences (IOP-China), Beijing in 2003. Between 2003 and 2008, he worked in IOP-China as intern, assistant professor and associated professor. In 2008, he joined NTT Basic Research Laboratories as Research Associate and Senior Research Associate. In 2013, he became a special assigned professor in IOP-China. In 2016, he joined University of science and technology of China as professor.

His team is dedicated to develop the scalable superconducting quantum computing. He has been responsible for developing several generations of highly coherent superconducting quantum processors, setting up ultra-low noise control and readout platform at millikelvin temperatures, and building up software and hardware of the room-temperature electronics. They developed a two-dimensional programmable superconducting quantum processor, Zuchongzhi, which is composed of 66 functional qubits in a tunable coupling architecture. Based on this state-of-the-art quantum processor, they achieved larger-scale random quantum circuit sampling, with a system scale of up to 60 qubits and 24 cycles and therefore exhibited strong quantum advantage. The achieved sampling task is about 6 orders of magnitude more difficult than that of Sycamore. in the best classic simulation.

ABSTRACT

Day 1 Dec-2 2021
Session 1 09:00-09:45

Quantum Control of Spins in Solids and Its Applications

Jiangfeng Du
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University of Science and Technology of China, China

Quantum control of systems plays an important role in modern science and technology. Spin system is an important platform for quantum control and promises various fascinating applications in quantum information science. In this talk, I would like to present our research progresses in quantum control over spins in solids, including the decoherence suppressing and high-fidelity quantum gate operations. Our experimental studies of its applications in quantum computation, quantum sensing, and fundamental physics research will also be presented.

Day 1 Dec-2 2021
Session 1 09:45-10:30

On Quantum Computational Supremacy

Scott Aaronson
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The University of Texas at Austin, USA

In Fall 2019, a team at Google made the first-ever claim of "quantum computational supremacy"---that is, a clear quantum speedup over a classical computer for some task---using a 53-qubit programmable superconducting chip called Sycamore. Since then, a group at USTC in China has made several additional claims of quantum supremacy, using both superconducting qubits and "BosonSampling" (a proposal by me and Alex Arkhipov from 2011) with ~100 photons in an optical network.

In addition to engineering, these experiments built on a decade of research in quantum complexity theory. This talk will discuss questions like: what exactly were the contrived computational problems that were solved? How does one verify the outputs using a classical computer?

And crucially, how confident are we today that the problems are really hard for classical computers?

Day 1 Dec-2 2021
Session 1 10:45-11:30

High-fidelity gates in a coupled super-conducting - qubit system

Hai-Feng Yu
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Beijing Academy of Quantum Information Sciences, China

In this talk, firstly, I will introduce advantages /disadvantages and characterization methods of several most used quantum gates for multi-qubit system. Secondly, I will focus on our recent experimental results, here we use two qubits coupled via a frequency-tunable coupler which can adjust the coupling strength, and demonstrate the CZ gate using two different schemes, adiabatic and diabatic methods. The Clifford based Randomized Benchmarking (RB) method is used to assess and optimize the CZ gate fidelity. The fidelity of adiabatic and diabatic CZ gates are99.53(8)%and98.7 2(2)%,respectively. Finally, the influences of crosstalk on gate fidelity when quantum gates are operated simultaneously in a multi-bit system will be analyzed.

Day 1 Dec-2 2021
Session 1 11:30-12:15

Superconducting quantum computing

Xiaobo Zhu
xbzhu16@ustc.edu.cn
University of Science and Technology of China

In this talk, I will show our recent progress with our collaborators on superconducting multi-qubits system. We designed and fabricated several versions of quantum processor, on which integrated up to 66 quibts. The fidelity of single-bit gate and two-bit gate are calibrated by randomized benchmarking or parallel cross-entropy benchmarking. For the single-qubit gate, the average error is ~0.14% and that of the two-qubit gate is ~0.59%. I will also show some of the multi-qubits experiment results, e.g., genuine multiparticle entanglement for 12 superconducting qubits[1], quantum walks on a programmable two-dimensional 62-qubit superconducting processor[2], and strong quantum advantage[3].

References:

[1] Phys. Rev. Lett. 122, 110501 (2019).

[2] Science, 372, 948 (2021).

[3] arXiv:2106.14734; arXiv:2109.03494

Day 1 Dec-2 2021
Session 2 14:00-14:45

Quantum computation of molecular structure using data from challenging-to-classically-simulate nuclear magnetic resonance experiments

*† Thomas E. O'Brien, ‡ Lev. B. Ioffe, ‡ Yuan Su, § David Fushman, ‡ Hartmut Neven, ‡ Ryan Babbush, and ‡ Vadim Smelyanskiy
*lead presenter
† teobrien@google.com, Google Quantum AI, Munich, Germany
‡ Google Quantum AI, California, USA
§ University of Maryland, Maryland, USAChina

We propose a quantum algorithm (ArXiv:2109.02163) for inferring the molecular nuclear spin Hamiltonian from time-resolved measurements of spin-spin correlators, which can be obtained via nuclear magnetic resonance (NMR). We focus on learning the anisotropic dipolar term of the Hamiltonian, which generates dynamics that are challenging to classically simulate in some contexts. We demonstrate the ability to directly estimate the Jacobian and Hessian of the corresponding learning problem on a quantum computer, allowing us to learn the Hamiltonian parameters. We develop algorithms for performing this computation on both noisy near-term and future fault-tolerant quantum computers. We argue that the former is promising as an early beyond-classical quantum application since it only requires evolution of a local spin Hamiltonian. We investigate the example of a protein (ubiquitin) confined in a membrane as a benchmark of our method. We isolate small spin clusters, demonstrate the convergence of our learning algorithm on one such example, and then investigate the learnability of these clusters as we cross the ergodic-MBL phase transition by suppressing the dipolar interaction. We see a clear correspondence between a drop in the multifractal dimension measured across many-body eigenstates of these clusters, and a transition in the structure of the Hessian of the learning cost-function (from degenerate to learnable). Our hope is that such quantum computations might enable the interpretation and development of new NMR techniques for analyzing molecular structure.

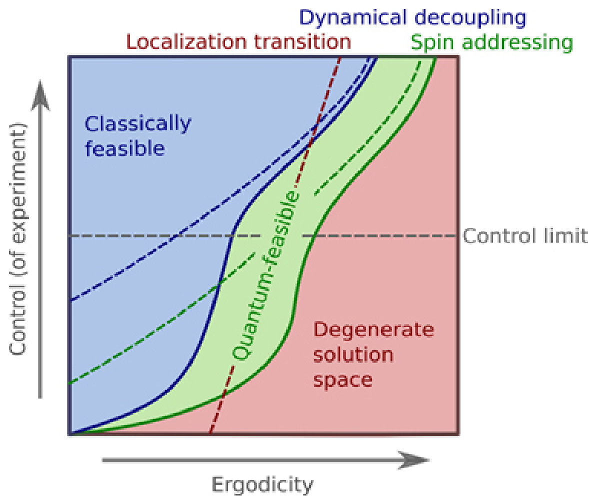

FIG. 1. Cartoon of the "phases of learnability" of a quantum Hamiltonian. In the red region, the set of experimental data is insufficient to distinguish candidate Hamiltonians. In the blue region, the experimental data is sufficient to learn Hamiltonian structure, but this learning may be achieved classically, rendering a quantum computer unnecessary. The intermediary green region is the area we target with our quantum assisted Hamiltonian learning algorithm.

Reference:

M.J. Pacholski, G. Lemut, O. Ovdat, I. Adagideli, and C.W.J. Beenakker *Phys. Rev. Lett. 126, 226801 (2021).*

Day 1 Dec-2 2021
Session 2 14:45-15:30

Si platform for implementing spin-based quantum computing

Seigo Tarucha
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RIKEN Center for Emergent Matter Science and RIKEN Center for Quantum Computing, JapanChina

Silicon (Si) is a promising platform for implementing spin-based quantum computing with qubits of electrons (or holes) in QDs, because the qubits in Si are capable of a long intrinsic decoherence time (> msec), a high temperature operation (> K), and compatiblity in device fabrication with semiconductor manufacturing. But improving the fidelity of these operations and increasing the qubit number are still challenges in realizing the fault-tolerant quantum computation.

I will first discuss how to improve the fidelities of single- and two-qubit gates, initialization and readout beyond the quantum error correction threshold, 99 %. For the single qubits the fidelity higher than 99.9% has been achieved [1] but yet limited to 98 % for the two-qubit gates [2]. This is assigned to slow operation compared to the dephasing and noise coming from the exchange coupling of qubits. To deal with these problems we use a micro-magnet technique [3] for a Si/SiGe double QD to make fast the single spin qubit drive and finally achieve the two-qubit gate fidelity above 99% [4]. For the initialization and readout we use a quantum non-demolition method to raise the fidelity above 99 % [5].

I will finally review recent efforts to scale up the qubit system based on the semiconductor technology.

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Day 1 Dec-2 2021
Session 2 15:30-16:15

Progress on trapped ion quantum computing and networking

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In this talk, I will review the recent progress on trapped ion quantum computing and networking, including the realization of large-scale quantum simulation of dynamics in Hubbard-type models beyond the classical simulation capability and the implementation of the dual-type qubits with crosstalk errors significantly below the error threshold, a key component for quantum error correction and fault-tolerant quantum computing.

Day 1 Dec-2 2021
Session 2 16:30-17:15

Quantum computing with trapped ions

F. Schmidt-Kaler*, J. Hilder, D. Pijn, D. Wessel, C. Melzer, A. Müller, J. Wagner, O. Onishchenko, A. Stahl, M. Orth, F. Stopp, B. Lekitsch, U. Poschinger
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Quantum technologies open up new computation applications, new simulation and sensing techniques. Here we focus on a quantum computer based on trapped ion qubits. We use segmented micro traps and dynamically shuttle ions, reorder this way qubit registers according to the required quantum algorithm. This allows for a high qubit connectivity in combination scalable high quantum gate fidelities. Currently we achieve 99.995% fidelity for single and 99.75% for two-qubit gates. On the way towards quantum error correction we have implemented fault-tolerant parity readout [1]. Fabrication methods, electronics control infrastructure and optical qubit control [2] is pushed for a 50 up to 100 qubit device, and we are investigating further scalability by trap-to-trap ion transports [3]. We have built the full computational stack, including a user interface (see https://iquan.physik.uni-mainz.de/) and have low latency interface to a classical high performance computer nearby. In this combination of HPC and QC, we are working towards a simulation of complex chemical structures and reactions.

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Day 1 Dec-2 2021
Session 2 17:15-18:00

Experimental simulation of PT-symmetric quantum system using single trapped ion

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Exceptional points (EPs) of a non-Hermitian Hamiltonian with parity-time-reversal (PT) symmetry have the potential to drastically enhance the capabilities of metrology and sensing through their power-law growing sensitivity to external perturbation. With the ability of generating and tuning dissipation in a single trapped ion system, we observe rich dynamics and detailed quantum phase transitions from the PT-symmetric phase to the symmetry-breaking phase. In this single qubit full quantum system, we develop a method to precisely determine the location of EP without any fitting parameter, and extract the eigenvalues in a unified way through all parameter regions. We can also obtain the full density matrix by quantum state tomography. Finally, we suggest from theoretical analysis that the periodically driving PT-symmetric non-Hermitian system can be used to measure the magnitude, frequency and phase of time-dependent perturbation with EP enhancement.

Day 1 Dec-2 2021
Session 2 18:00-18:45

The next step in Quantum Computing: From NISQ to PISQ

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Given the impeding timeline of developing good quality quantum processing units, it is the moment to rethink the approach to advance quantum computing research. Rather than waiting for quantum hardware technologies to mature, we need to start assessing in tandem the impact of the occurrence of quantum computing in various scientific fields. However, to this purpose, we need to use a complementary but quite different approach than proposed by the NISQ vision, which is heavily focused on and burdened by the engineering challenges(Fig).
It is not the long-term solution but it will allow universities to currently develop research on quantum logic and algorithms and companies can already start developing their internal know-how on quantum solutions.

Reference:
M.J. Pacholski, G. Lemut, O. Ovdat, I. Adagideli, and C.W.J. Beenakker Phys. Rev. Lett. 126, 226801 (2021).

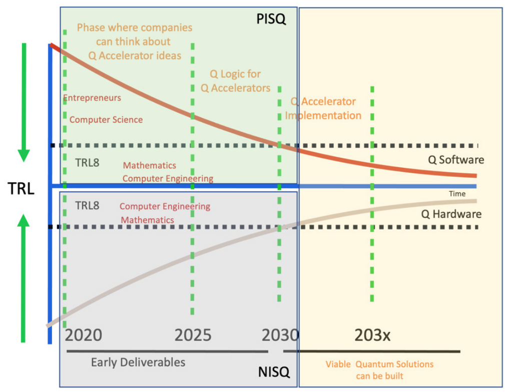

Figure 1: Long term quantum research in different fields As shown in Figure 1, that is why we propose and advocate the PISQ-approach: Perfect Intermediate-Scale Quantum computing based on the already known concept of perfect qubits. This will allow researchers to focus much more on the development of new applications by defining the algorithms in terms of perfect qubits and evaluate them on quantum computing simulators that are executed on supercomputers.

Day 2 Dec-3 2021
Session 3 9:00-9:45

Recent Progress in Coherent Ising Machines

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In this talk we will discuss various recent results on coherent Ising machines (CIM): the quantum principles and application as heuristic algorithms on current digital platform.

1. Quantum principles of CIMs

A coherent Ising machine (CIM) is an analog neural network consisting of optical parametric oscillators (OPO) and capable of finding optimum or sub-optimum solutions for combinatorial optimization problems.[1,2] An optical delay line (ODL-)CIM implements a target (Ising) Hamiltonian directly in optical domain.[3-5] Quantum correlation is formed among OPOs at below threshold, which induces a collective symmetry breaking at above threshold toward an optimum solution. The degree of entanglement in OPO network reaches a maximum at threshold [6], when a decision is induced by the formed quantum correlation (collective pitchfork bifurcation). A measurement feedback (MFB-)CIM implements a target Hamiltonian indirectly using digital electronic circuits.[7-9] In this case, the quantum correlation between internal and external (measurement) fields is converted to classical correlation among OPOs via measurement induced state reduction.

2. CIM as a digital algorithm

Although CIM has been studied as a computing hardware platform in the past, the quantum model in its simplest version can be implemented as a heuristic algorithm on current digital platform such as GPU and FPGA. This cyber-CIM is one of the quantum inspired optimization (QIO) approaches. One advantage of QIO is that we can create an ideal quantum machine with arbitrary precision and controlled (optimized) noise. The CIM with chaotic amplitude control (CAC) [10] and discrete simulated bifurcation machine (dSBM) [11] are representative examples of QIO. CIM-CAC and dSBM are very similar in their principles, so the difference between the two algorithms is very subtle. In general, dSBM is a faster solver for easy instances but constantly struggles for harder instances.

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Day 2 Dec-3 2021
Session 3 09:45-10:30

Photonic quantum computational advantage

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The main challenge for scaling up photonic quantum technologies is the lack of perfect quantum light sources. We have pushed the parametric down-conversion to its physical limit and produce two-photon source with simultaneously a collection efficiency of 97% and an indistinguishability of 96% between independent photons. Using a single quantum dot in microcavities, we have produced on-demand single photons with high purity (>99%), near-unity indistinguishability, and high extraction efficiency—all combined in a single device compatibly and simultaneously. Based on the high-performance quantum light sources, we have implemented boson sampling—which is an intermediate model of quantum computing, a strong candidate for demonstrating quantum computational advantage and refuting Extended Church Turing Thesis—with up to 113 photon clicks after a 144-mode interferometer. The photonic quantum computer, Jiuzhang, yields an output state space dimension of 10^43 and a sampling rate that is 10^24 faster using the state-of-the-art simulation strategy on supercomputers.

Day 2 Dec-3 2021
Session 3 10:45-11:30

Developing technologies towards an error-corrected quantum computer

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In this talk, I will give an overview on the technology developments in Google Quantum AI Lab. I will describe how these developments enabled us to build quantum systems with higher computational power for algorithms with higher complexities. A proof-of-principle example was given by the demonstration of beyond-classical computation (AKA quantum supremacy), where quantum computers can outperform classical counterparts on certain computational tasks. In the post-beyond-classical era, we are focusing on building technologies for an error-corrected quantum computer for fault-tolerant computations. I will describe a sequence of milestones we hope to achieve en route to such an error-corrected quantum machine, as well as the progress we have made towards achieving those milestones in Google Quantum AI Lab.

Day 2 Dec-3 2021
Session 3 11:30-12:15

Semiconductor nanolayers: A new platform for developments of quantum and topological devices

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Semiconductor InAs and InSb nanowires have been demonstrated as one of the most promising materials systems for realizing topological superconducting structures in which Majorana bound states can be created and manipulated [1,2]. For achieving quantum computing with Majorana bound states, an efficient scheme for braiding Majorana bound state needs to be developed. In this respect, proposals of using branched nanowires and two-dimensional planar structures have been envisioned. In this talk, I will report on our recent developments in epitaxial growth of free-standing InAs and InSb nanoplates and in building quantum devices and superconducting Josephson junction devices with these nanoplates. These nanoplates were grown by molecular beam epitaxy (MBE) [3,4] and exhibit excellent transport properties [5-10]. The advantages of employing these nanoplates include flexibilities of transferring them to desired substrates for device fabrication and of directly contacting them with different metals and superconductors. Several quantum devices have been fabricated using the MBE-grown nanoplates. In particular, we have realized InSb nanoplate quantum dot devices [5] and Josephson junction devices [6-8]. Perspectives of achieving topological quantum devices with these nanoplates will also be presented and discussed.

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Day 2 Dec-3 2021
Session 4 14:00-14:45

Coherent errors in quantum error correction and fault-tolerant quantum computation

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Quantum error correction (QEC) is the key for the fault-tolerant quantum computation, and their experimental realization will be the next milestone. A remarkable result of QEC is the error threshold theorem, which is established on stochastic error models. However, non-stochastic errors or coherent errors may dominate the quantum computing chips, and cannot be excluded. Therefore, we study the performance of quantum error correction codes (QECCs) under the non-stochastic single qubit coherent errors and detection-induced coherent errors due to the imperfectness of practical implementations of stabilizer measurements, after running a quantum circuit. Considering the most promising surface code, we find that the detection-induced coherent error will result in undetected error terms, which will accumulate and evolve into logical errors. However, we show that this kind of errors will be alleviated by increasing the code size, akin to eliminating other types of errors discussed previously. We also find that with both the single qubit coherent errors and detection-induced coherent errors, the exact surface code becomes an approximate QECC.

In the last few minutes, I will briefly present the new quantum software package—Qcover, which is under development in our group. The core of Quantum Approximate Optimization Algorithm (QAOA) is to search the optimal parameters that minimize the expectation value of target Hamiltonian via variational method. The Qcover present here, can efficiently simulate QAOA process to obtain the optimal parameters based on graph algorithm. It will accelerates the coming of quantum advantage with the assistant of NISQ hardware.

Day 2 Dec-3 2021
Session 4 14:45-15:30

Perspectives on single atom based scalable silicon quantum computing

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Silicon quantum dots is one of the most promising quantum computing platforms. After the atomic qubits in silicon have seen tremendous progress in the past 20 years, the next challenge for the atom qubits in silicon is to tailor functional components for scalable quantum computing. Considering the scalable requirements, the hole spin in the Boron atom with EDSR control could be a game-changer. It benefits greatly from the reduced driving component size. Also, using dipole-dipole coupled two qubits could enlarge the qubit footprint and realize a dipole-dipole coupled two-qubit gate. In the end, I am going to outlook the potential methods to build quantum connections between photons and spins in the Boron qubits for a quantum internet. Combined, I will present a blueprint for a scalable atomic silicon chip with those novel quantum gates in Boron qubits.

Day 2 Dec-3 2021
Session 4 15:45-16:30

Deconfinement of Majorana vortex modes in a topological superconductor

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A spatially oscillating pair potential drives a deconfinement transition of the Majorana bound states in the vortex cores of a Fu-Kane heterostructure (a 3D topological insulator on a superconducting substrate, in a perpendicular magnetic field). In the deconfined phase at zero chemical potential the Majorana fermions form a dispersionless Landau level, protected by chiral symmetry against broadening due to vortex scattering. Unlike a conventional electronic Landau level, the Majorana Landau level has a non-uniform density profile: quantum interference of the electron and hole components creates spatial oscillations with a wave vector set by the Cooper pair momentum that drives the deconfinement transition. The striped pattern provides a means to measure the chirality of the Majorana fermions. As an outlook to future investigations, we will discuss the possibility to braid the delocalized Majorana fermions.

Reference:

M.J. Pacholski, G. Lemut, O. Ovdat, I. Adagideli, and C.W.J. Beenakker Phys. Rev. Lett. 126, 226801 (2021).

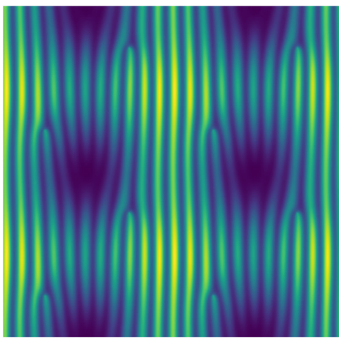

Fig1. Intensity profile of the deconfined phase of a Majorana zero mode in a vortex lattice shows a pronounced periodic modulation in the direction parallel to the Cooper pair momentum, with bifurcation points at the vortex cores.

Day 2 Dec-3 2021
Session 4 16:30-17:15

Quantum Computation and Simulation - Spins Inside

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Quantum computation has captivated the minds of many for almost two decades. For much of that time, it was seen mostly as an extremely interesting scientific problem. In the last few years, we have entered a new phase as the belief has grown that a large-scale quantum computer can actually be built. Quantum bits encoded in the spin state of individual electrons in silicon quantum dot arrays, have emerged as a highly promising direction [1]. In this talk, I will present our vision of a large-scale spin-based quantum processor, and ongoing work to realize this vision.
First, we created local registers of spin qubits with sufficient control that we can program arbitrary sequences of operations, implement simple quantum algorithms [2], and achieve two-qubit gate fidelities of more than 99.5% [3]. In linear quantum dot arrays, we now achieve universal control of up to six qubits [4]. Second, we have explored coherent coupling of spin qubits at a distance via two routes. In the first approach, the electron spins remain in place and our coupled via a microwave photon in a superconducting on-chip resonator. After reaching the strong coupling regime of a single spin and a single photon [5], we have recently observed coherent spin-spin interaction at a distance, mediated by off-resonant photons [6]. In the second approach, spins are shuttled along a quantum dot array, preserving both the spin projection [7] and spin phase [8].

Third, in close collaboration with Intel, we have fabricated and measured quantum dots using all-optical lithography on 300 mm wafer, using industry-standard processing [9], demonstrating excellent qubit performance. We expect that this industrial approach to nanofabrication will be critical for achieving the extremely high yield necessary for devices containing thousands of qubits.

When combined, the progress along these various fronts can lead the way to scalable networks of high-fidelity spin qubit registers for computation and simulation.

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Day 2 Dec-3 2021
Session 4 17:15-18:00

Superconducting quantum computing chip with a vertically accessed two-dimensional array of qubits

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Superconducting circuits are one of the most promising platforms for quantum computing. Several groups have already demonstrated operations of quantum computing chips with tens of qubits integrated in a two-dimensional lattice. With the rapidly improving fidelities of the control gates and readouts, more and more advanced computation becomes achievable.

There are a few different architectures under intensive studies, roughly classified with tunable-frequency or fixed-frequency qubits and with tunable or fixed couplings. The less tunability tends to lead the longer coherence and less demands for wiring. On the other hand, the system could be vulnerable to the device parameter fluctuations in the fabrication as well as the energy coincidences with two-level fluctuators and the residual interactions between neighboring qubits. Apparently, there is a trade-off.

In this talk, we introduce our approach with a square lattice of fixed-frequency transmon qubits directly coupled with their nearest neighbors via capacitors. The circuit is controlled and read out only through microwave signals. To realize a tile-able design and mitigate the wiring issues in the planar approaches, we bring the control and readout lines vertically to the chip. We report the progress on the design and characterization of the chips and discuss the possible improvements and limitations.

POSTER LIST

01. Strong and Controllable Spin–Orbit Interactions in Epitaxially Grown Inas Nanosheets
Furong Fan | Peking University

02. Selective Area Epitaxy of Pbte-Pb Hybrid Nanowires on a Lattice-Matched Substrate
Yuying Jiang | Tsinghua University

03. Drastic Increase of Channel Capacity in Quantum Secure Direct Communication Using Masking
Haoran Zhang | Tsinghua University

04. Realization of Quantum Secure Direct Communication Over 100 km
Haoran Zhang | Tsinghua University

05. Towards Practical Quantum Computers: Transmon Qubit With a Lifetime Approaching 0.5 Milliseconds
Yingshan Zhang | BAQIS

06. Thermal Variational Quantum Simulation on a Superconducting Quantum Processor
Shangshu Li | Institute of Physics CAS

07. Site-Controlled In-Plane Si and Ge Nanowires
Jianhuan Wang | BAQIS

08. Chern Insulator State in Mbe Grown Mnbi2te4 Thin Films
Yang Feng | BAQIS

09. Characterizing Noise Correlation and Enhancing Coherence via Qubit Motion
Jiaxiu Han | BAQIS

10. Observation of Strong and Weak Thermalization in a Superconducting Quantum Processor
Zhenghang Sun | Institute of Physics CAS

11. Growth And Characterization of High-Quality Ge/Sige Planar Heterostructure for Hole Qubit
Jieyin Zhang | BAQIS

12. Suppressing Andreev Bound State Zero Bias Peaks Using A Strongly Dissipative Lead
Shan Zhang | Tsinghua University

13. A Quantum Convolutional Neural Network on NISQ Devices
Shijie Wei | BAQIS

14. Quantum Machine Learning on Superconducting Quantum Computer
Ruixia Wang | BAQIS

15. Implementation of Non-Hermitian Hamiltonian on Trapped Ion Platform
Liangyu Ding | Renmin University of China

16. Quantum Capacitance of Holes in Planar Germanium
Jiankun Li | BAQIS

17. Machine Learning in Nitrogen-Vacancy System
Huili Zhang | Tsinghua University

18. Fabrication and Quantum Oscillations of Insb Nanosheet/Hbn/ Graphite Heterostructured Devices
Li Zhang | Peking University

19. Large Zero-Bias Peaks and Dips in a Four-Terminal Thin Inas-Al Nanowire Device
Huading Song | BAQIS

20. Topological Dynamical Decoupling
Jiang Zhang | BAQIS

21. Vacuum-Gap Transmon Qubits Realized Using Flip-Chip Technology
Xuegang Li | BAQIS

22. Low-Temperature Quantum Oscillations in P-Type Multi-Channel Silicon Nanowire Junctionless Transistors
Jundong Chen | Institute of Semiconductors CAS

23. Experimental Implementation of Universal Holonomic Quantum Computation on Solid-State Spins with Optimal Control
Yang Dong | University of Science and Technology of China

24. Detection of Charge States of an Inas Nanowire Triple Quantum Dot With an Integrated Nanowire Charge Sensor
Weijie Li | Peking University

25. Numerical Study of Pbte-Pb Hybrid Nanowires for Engineering Majorana Zero Mode
Zhan Cao | BAQIS

26. Quantum Optimization for Polynomials: Theory and Experiment
Pan Gao | BAQIS

27. Analog Quantum Simulation of Discrete Time Crystal
Jingning Zhang | BAQIS

28. Quantum Interference between Independent Solid-State Single-Photon Sources
Xiang You | University of Science and Technology of China

29. Low-Decoherence Quantum Information Transmittal Scheme Based on the Single-Particle Various Degrees of Freedom Entangled States
Jiangmei Tang | Nanjing University of Aeronautics and Astronautics

30. Topological Phase Transition in a Semiconductor Insb Nanolayer
Zhihai Liu | Peking University

31. Universal Conductance Scaling of Andreev Reflections Using a Dissipative Probe
Gu Zhang | BAQIS

32. Secure End-To-End Quantum Network Using Present-Day Technology and Qsdc
Dong Pan | BAQIS

33. Operating System for NISQ-era Quantum Computing
Yulong Feng | BAQIS

34. Quantum Speed Limit Quantified by the Changing Rate of Phase
Yujun Zheng | Shandong University

35. Scalable Quantum i/o: Integrated Cryogenic Microwave Components in Flexible Stripline Structures
Zibo Wu | Delft Circuits

36. Double Fu-teleportation and anomalous Coulomb blockade in a mixed Andreev-Majorana superconducting island
Yiru Hao | Tsinghua University

37. Maxwell Demonand Quantum Non-locality
Mengjun Hu | BAQIS

All posters will be exhibited both onsite and online. A seperate Zoom meeting has been scheduled for online discussion of the posters.

- ***Onsite Poster Exhibition***: *Reception Hall (1st floor)*
- ***Online Poster Exhibition:*** http://qpqis2021.baqis.ac.cn/PosterGallery.html.
- ***Poster online discussion:*** *Dec.2 7:30-8:30 pm*
  Zoom Meeting ID - 894 6010 4882
  Passcode: Poster

IMPORTANT INFORMATION

Due to the current measures for COVID-19 containment, we have to restrict IN-PERSON participants to those who have been granted access to BAQIS building on a regular basis for work or collaboration.

We'd like to remind IN-PERSON participants to bring your BAQIS badge for access to the BAQIS Building.

Participants without a BAQIS badge are invited to attend the conference ONLINE.

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