SQST

The 1st International Conference on

SIAM QUANTUM SCIENCE AND TECHNOLOGY

December 1-4, 2024

Ao Nang, Krabi, Thailand

ABSTRACT
BOOK

Preface

Quantum Science and Technology have emerged in recent years as significant global research areas, attracting attention and contributions from government sectors, academic institutions, and industries. Thailand is joining this movement, establishing a research funding scheme to support cutting-edge quantum technology research.

Siam Quantum Science and Technology (SQST-2024) will be Thailand's first international conference focused on quantum science and technology research. This event reflects the country's growing quantum-research community and the government's commitment to advancing this frontier science.

The conference aims to bring together researchers from Thailand and around the world, fostering collaboration, knowledge-sharing, and inspiring young scientists in the field. The 4-day event, held in the first week of December, will feature invited talks, contributed talks, and poster sessions selected from submitted abstracts.

We warmly welcome all participants from around the globe and invite you to join us in beautiful Krabi province, Thailand.

SQST 2024
SIAM QUANTUM SCIENCE AND TECHNOLOGY

The SQST 2024 conference is hosted by
the Faculty of Science, Prince of Songkla University, in collaboration with the Faculty of Science, King Mongkut's University of Technology Thonburi and Quantum Technology Research Initiative collaboration (QTRic).

Sponsored by

Welcoming Message

from Head of Quantum Technology Research Initiative Collaboration (QTRic)

On behalf of the Quantum Technology Research initiative collaboration or QTRic in Thailand, it is my honor and privilege to welcome you to the SQST Conference here in Krabi, Thailand. This event marks a significant milestone as it brings together an incredible assembly of international attendees, all united by a shared passion for quantum research and technology. Over the course of this conference, we will delve into diverse topics through keynote talks covering the five pillars of quantum technology: Quantum metrology and sensing, Quantum computation, algorithms, and simulation, Quantum information theory, Quantum communication, networks, and cryptography and Quantum technologies in general. We will also highlight regional advancements through ASEAN talks, fostering collaboration among neighboring countries, and showcase the remarkable ongoing research in Thailand through our QTRic sessions.

I would like to express our heartfelt gratitude to all the participants who have traveled from near and far to join us. We hope that this stunning location, with its breathtaking views of Krabi, inspires not only relaxation but also a wealth of new ideas and perspectives. Let the beauty of our surroundings serve as a catalyst for groundbreaking research discussions and the strengthening of existing connections while building new, meaningful collaborations. Thank you once again for being here, and let's make this conference a memorable and impactful experience for everyone.

Warm regards,
Worawat Meevasana

Opening Remarks

from the Dean Faculty of Science, Prince of Songkla University

It is with great pleasure that I extend my warmest welcome to all participants of the 1st International Conference on Siam Quantum Science and Technology (SQST 2024), hosted by the Faculty of Science, Prince of Songkla University, in collaboration with King Mongkut's University of Technology Thonburi and the Quantum Technology Research Initiative Consortium (QTRic), here in the beautiful province of Krabi, Thailand.

At the national level, Thailand recognizes the transformative potential of quantum technology. Our government has placed significant emphasis on its development as a critical driver of innovation, scientific advancement, and sustainable growth. This reflects our collective commitment to leveraging cutting-edge research and fostering a future-ready society.

SQST 2024 is a pioneering effort to advance quantum science and technology by bringing together researchers, scholars, and practitioners from around the world. This conference aims to showcase the capabilities of the Quantum Technology Research Initiative Consortium (QTRic) and its high-quality research network, attract global recognition, and foster collaborations between Thai and international researchers. Our ultimate vision is to build an ASEAN-level consortium that promotes research excellence, facilitates knowledge exchange, and strengthens our collective presence in our region.

This conference is especially significant for fostering global collaboration in quantum science and technology. We are deeply honored to welcome some of the world's foremost experts in quantum research, representing four continents. Their participation brings invaluable perspectives and sets the stage for groundbreaking discussions and innovations that have the potential to reshape the field. As a unique platform for collaboration, this event bridges global leaders in quantum science with the dynamic Thai quantum community, creating an inspiring environment of partnership and shared vision that transcends geographical boundaries.

We appreciate the support and participation of every individual and organization that has made this event possible. Your involvement strengthens our shared commitment to advancing quantum science and technology, both regionally and globally.

Welcome to Krabi and thank you for joining us on this exciting journey to shape the future of quantum research.

Warm regards,
Anchana Prathep

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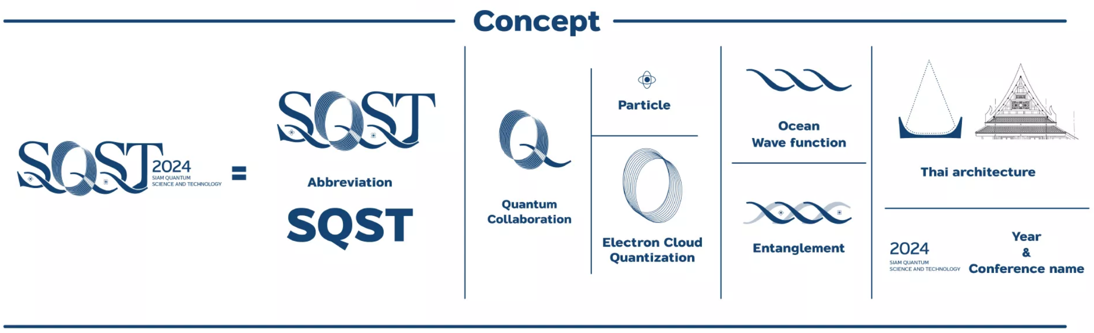
Concept of SQST Logo



Color : PSU Navy Blue / Price of Songkla University Navy Blue

Useful Information

★ Sustainable Event

The SQST conference has been organized and followed Sustainable Event basic guidelines by Thailand Convention and Exhibition Bureau (TCEB) and has planned an event in a sustainable way to avoid the carbon footprint which could occur across five key areas: documentation, food and beverage, transportation, energy use, and decorations. The Faculty of Science at Prince of Songkla University sincerely appreciates your participation in making this event a success.

★ Talks

Keynote talks will be 45 minutes each, while other presentations are set for 30 minutes. ASEAN talks will highlight work from neighboring ASEAN countries to foster regional collaboration, while QTRic sessions will showcase ongoing quantum technology research in Thailand.

★ Poster Sessions & Afternoon Discussions

Poster Sessions & Afternoon Discussions are fantastic occasions to discuss science and are super important parts of the SQST conference. We have got flip charts and a chill area around the conference area. Come on over and enjoy it!

★ Food & Beverage

We provides coffee breaks and lunches for 4 days, Welcome Reception on the 1st December, and Conference dinner on the 2nd December for registered participants. Just a heads up - the SQST mug you get at registration can be used for the event and even after it's over!

Map of Aonang Villa Resort

Our SQST registration desk is in front of the Chonlatee Meeting room (O, on the map), where the oral presentations will take place. Besides, the place for lunches will be at Klang Le restaurant (R, on the map), just nearby the restaurant is Sai-Natee room where the poster presentations will be. For participants who stay at Aonang Villa Resort, please contact the hotel reception desk at location (J).

Conference Program

December 1, 2024

Time	Activities
08:00-08:45	Registration
08:45-09:15	Opening Ceremony
09:15-10:00	Keynote Quantum Computing with Neutral Atoms Ivan Deutsch
10:00-10:30	QTRic Quantum Simulation and Sensing with Neutral Rydberg Atoms Nithiwadee Thaicharoen
10:30-10:50	Coffee Break
10:50-11:20	ASEAN Building and Controlling a Superconducting Quantum Computer Yung Szen Yap
11:20-11:50	ASEAN Designing Hybrid Quantum Computing Pipelines with NVIDIA CUDA-Q Dylan Josh Lopez
11:50-12:50	Lunch
12:50-14:10	Poster Presentation
14:10-14:40	Afternoon Discussion
14:40-15:10	ASEAN Holomorphic Quantization of Qubit Geometry Hishamuddin Zainuddin
15:10-15:40	Invited Energetic Advantages for Quantum Agents Jayne Thompson
15:40-16:00	Coffee Break
16:00-16:30	QTRic Quantum Machine Learning and the Journey to its Scalability Supanut Thanasilp
16:30-17:00	QTFT A Category Theory and Quantum Optimization Framework for Tackling Dynamic Business Challenges in Thailand Gun Pinyo and Panithi Suwanno
17:00-17:15	Break
17:15-20:15	Welcome Reception

Conference Program

December 2, 2024

Time	Activities
09:00-09:45	Keynote Quantum Agents and Non-Markovianity: How do identify them and what can they do? Mile Gu
09:45-10:15	Invited Time-Like Correlations and Retrodiction in Quantum Theory Francesco Buscemi
10:15-10:45	Invited Bandits Roaming in Hilbert Space Marco Tomamichel
10:45-11:05	Coffee Break
11:05-11:35	Invited Quantum Sensing: From Laboratory Innovation to Practical Precision Rainer H. Dumke
11:35-12:05	ASEAN Molecular Spectroscopy with Scattershot Boson Sampler Leong Chuan Kwek
12:05-13:05	Lunch
13:05-14:25	Poster Presentation
14:25-14:55	Afternoon Discussion
14:55-15:40	Keynote Can Precision Spectroscopy be performed in Ion Coulomb Crystals?- About Tests of Fundamental Physics and Multi-Ion Clocks Tanja E. Mehlstäubler
15:40-16:10	QTRic How Optical Clocks Will Transform Thailand Standard Time? Piyaphat Phoonthong
16:10-16:30	Coffee Break
16:30-17:00	Invited Nitrogen Vacancy Centres, a Versatile Testbed for Quantum Sensing and Simulations Soham Pal
17:00-17:30	Contributing Electron Spin Gates in a Scalable Diamond Quantum Register Timo Joas
17:30-18:00	Break
18:00-21:00	Conference dinner (and relaxing time afterward)

Conference Program

December 3, 2024

Time	Activities
09:00-09:45	Keynote Quantum non-Gaussian Light and Mechanics Radim Filip
09:45-10:15	Invited Super Lasers: Can we achieve the Heisenberg limit for laser coherence? Howard M. Wiseman
10:15-10:45	Invited Quantum-optimal Parameter Estimation in Optics and the Example of Source Separation Nicolas Treps
10:45-11:00	Coffee Break
11:00-11:30	Invited Optimal Control and Continuously Measured Quantum Systems Andrew N. Jordan
11:30-12:00	Invited Agnostic Phase Estimation David Arvidsson-Shukur
12:00-12:30	QTRic Enhancing Optoelectronic Properties through Quantum Dot Integration: Interface Engineering and 2D Materials for Semiconductor-based Devices Sukrit Sucharitakul
12:30-13:30	Lunch
13:30	Freestyle Excursion

Conference Program

December 4, 2024

Time	Activities
09:00-09:45	Keynote Networks for Modular Quantum Systems Rodney Van Meter
09:45-10:15	Invited Quantum Optics with Complex Media Sylvain Gigan
10:15-10:35	Coffee Break
10:35-11:20	Keynote Advances in Photonic Quantum Computing Anthony Laing and Emilien Lavie
11:20-11:50	Contributing Synchronizable Hybrid Subsystem Codes Theerapat Tansuwannont
11:50-12:20	QTRic Quantum Communication in Thailand Poompong Chaiwongkhot
12:20-13:30	Lunch and Closing Remarks
13:30	Departure

ORAL PRESENTATION

SIAM QUANTUM SCIENCE AND TECHNOLOGY

Keynote | 09:15-10:00, December 1, 2024

Quantum Computing with Neutral Atoms

Ivan Deutsch[1,*]

[1]Quantum New Mexico Institute, University of New Mexico, United States

Abstract

The race to build a fault tolerant quantum computer is in fully swing. But in which physical system should we encode quantum information? In classical computers the winner was clear – transistors in silicon in the integrated circuit architecture. For quantum computers the story is still be written. Research and development proceeds along multiple directions. Superconductivity circuits and atomic ion traps have long been the leading contenders. Recently, a dark horse candidate has emerged as a powerful competitor – neutral atoms trapped in laser light. Like their charged-ion cousins, neutral atoms are Nature's qubits – they are identical, well-controlled by electromagnetic fields, and can be prepared in nearly pure quantum states with the tools developed for laser cooling and coherent spectroscopy. They are the foundation of the world's most quantum coherent device – the atomic clock. In this talk I will describe the physics of quantum computing with optically-trapped neutral atoms and the cutting edge this up-and-coming architecture.

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QTric | 10:00-10:30, December 1, 2024

Quantum Simulation and Sensing with Neutral Rydberg Atoms

Nithiwadee Thaicharoen[1,*]

[1]Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Thailand

Abstract

There is growing interest in using Rydberg atoms for applications in quantum simulation and sensing. The tunable and strong long-range interactions and long lifetimes of highly excited Rydberg atoms open new opportunities for exploring the dynamics of strongly correlated many-body quantum systems. Additionally, the high electric polarizability of Rydberg states enables for sensitive electric field detection. In this talk, I will discuss the utilization of Rydberg-Rydberg interactions for the realization of a many-body Rydberg spin system. I will then discuss how Rydberg atoms can be utilized as atom-based electric field sensors through electromagnetically induced transparency and Autler-Townes splitting. Finally, I will provide an overview of the current state of Rydberg and cold neutral atom research in Thailand.

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ASEAN | 10:50-11:20, December 1, 2024

Building and Controlling a Superconducting Quantum Computer

Yung Szen Yap[1,2,*], **Rainer H. Dumke**[2,3,†]

[1]Faculty of Science, Universiti Teknologi Malaysia, Johor, Malaysia
[2]Centre for Quantum Technologies, National University of Singapore, Singapore
[3]Division of Physics and Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore

Abstract

A superconducting quantum computer consists of several essential elements: a quantum processor, a cooling system and a microwave system. We at the Rainer Dumke lab, Centre for Quantum Technologies are working on qubit fabrication and development of a custom microwave control system based on RFSoC FPGA. In some of our recent work, we attempt to study how noise impacts the performance of the quantum computer. We've developed a model to illustrate how control electronics noise affects the qubit system and found that the current bottleneck to achieving high-fidelity control lies in the limited qubit coherence time.

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ASEAN | 11:20-11:50, December 1, 2024

Designing Hybrid Quantum Computing Pipelines with NVIDIA CUDA-Q

Dylan Josh Domingo Lopez[1,2,3,4,*]

[1]Quantum Computing Society of the Philippines
[2]De La Salle University, Manila, Philippines
[3]Technological Institute of the Philippines, Quezon City, Philippines
[4]Chung Yuan Christian University, Taiwan

Abstract

Maximizing the use of quantum computers for business cases and operations during the NISQ Era requires combining computational power from CPUs and GPUs and existing QPUs. In this talk, Dylan will be introducing how to layout and design a hybrid quantum computing pipeline with NVIDIA CUDA-Q leveraging on GPUs for quantum algorithm prototyping and preparing a workflow. He will also demonstrate several use cases using VQAs and hybrid quantum neural networks for some domain applications.

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Holomorphic Quantization of Qubit Geometry

Hishamuddin Zainuddin[1,*], **Nurisya Mohd Shah**[2,†], **A. Hazazi A. Sumadi**[3,‡]
[1]School of Mathematics and Physics, Xiamen University Malaysia, Malaysia
[2]Department of Physics, Universiti Putra Malaysia, Malaysia
[3]Institute for Mathematical Research, Universiti Putra Malaysia, Malaysia

Abstract

The Riemann sphere is taken as the classical phase space of qubit geometry and then quantized using canonical group quantization. Adopting the natural holomorphic polarization, holomorphic spin operators can be constructed, reproducing the standard SU(2) algebra with interesting geometric properties. The method can also be generalized to qudits and multiple qubits using generalized Hopf fibration for CP^n and symmetric product of Riemann spheres respectively.

Keywords: Canonical group quantization, symplectic geometry, complex projective spaces.

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Invited | 15:10-15:40, December 1, 2024

Energetic Advantages for Quantum Agents

Jayne Thompson[1,*]

[1]Institute of High Performance Computing, Agency for Science, Technology and Research, Singapore

Abstract

AI has a growing energy foot print, the energetic cost of generating responses to user input is growing as we seek to automate ever more complex tasks. This cost is often benchmarked based on the amount of petaflops the device needs to execute to train or run model inference for latest generation AI models. Here we discuss interactive protocols which involve an agent interacting with its environment, to execute some task. We discuss the potential to get to smaller scale implementations with a quantum agent, and the capacity for this to change the fundamental lower bounds on the energetic cost of exhibiting a behavior or executing a task. We show that this leads to quantum agents having fundamentally lower energetic cost to exhibit a particular behavior, and that the gap between quantum and classical energetic cost can scale unboundedly.

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QTric | 16:00-16:30, December 1, 2024

Quantum Machine Learning and the Journey to its Scalability

Supanut Thanasilp[1,*]

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Abstract

Quantum systems are well known to create non-classical patterns. The thought that they could also be used to recognize highly complex patterns hidden in data is beyond excitement, leading to the young interdisciplinary field of quantum machine learning (QML). Nevertheless, while a quantum advantage in data analysis can be in principle achieved thanks to the exponentially large Hilbert space, the scalability of QML models has been in heated debates. The very same exponential large space can at the same time hinder the scalability if it is poorly handled. In this talk, I will give an overview of QML and discuss its scalability challenges including barren plateaus, exponential concentration, classical simulability.

QTFT | 16:30-17:00, December 1, 2024

A Category Theory and Quantum Optimization Framework for Tackling Dynamic Business Challenges in Thailand

Gun Pinyo[1,*], **Panithi Suwanno**[1,†]

[1]Quantum Technology Foundation (Thailand) QTFT

Abstract

In this presentation, we will explore QTFT's initiatives to develop a system-of-systems (SoS) framework for quantum optimization across complex enterprise networks, including supply chains, energy grids, aviation, and logistics. We will begin by examining a case study where we leverage IBM's 127-qubit systems on production to partially optimize the fleet routes for over 6,000 convenience stores in metropolitan areas of Thailand. Following this, we will introduce our SoS framework, known as SOR, and discuss how category theory underpins data interoperability with a rigorous mathematical foundation. Finally, we will outline our research direction, in collaboration with our customers, focusing on the application of quantum clustering to enhance SoS management and optimization.

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Keynote | 09:10-09:45, December 2, 2024

Quantum Agents and Non-Markovianity: How do identify them and what can they do?

Mile Gu[1,*]

[1]Nanyang Quantum Hub, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore

Abstract

Autonomous agents permeate science and society, from Maxwell's hypothetical demons that extract energy from the environment to autonomous vehicles navigating busy streets. Such devices derive capability from non-Markovian behaviour - their decisions at each time are dependent not only on present stimuli but also on experiences in the distant past. This non-Markovianity powers such devices, allowing them to perform contextual tasks that seem to require intelligence. Yet, traditional treatments and understanding of such agents assumed a classical reality, where both agents and their environment exist in a classical universe modelled by classical states.

In this presentation, I survey present research at the Nanyang Quantum Hub, where we ask: what happens in a quantum universe where either agents or their environments are quantum mechanical? I will then discuss in more detail two particular directions in which we have had fruitful research outcomes: (1) quantum-enhanced dimensional reduction, where agents can perform a range of complex tasks far more effectively when the memory they hold is quantum mechanically and (2) a means to identify when the non-Markovian behaviour carried by a quantum device must be non-classical.

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Invited | 09:45-10:15, December 2, 2024

Time-Like Correlations and Retrodiction in Quantum Theory

Francesco Buscemi[1,*]

[1]Quantum Mathematical Informatics Group, Department of Mathematical Informatics, Nagoya University, Japan

Abstract

Extending classical multitime processes to quantum dynamics presents significant challenges, particularly due to the ”no information without disturbance” principle. Instead of hindering progress, these challenges have driven the development of innovative and sometimes unconventional methods that question traditional interpretations of quantum mechanics. In this talk I will review some of the results we have obtained in the last decade that shed light on the role of time-like correlations and retrodiction in quantum theory.

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Invited | 10:15-10:45, December 2, 2024

Bandits Roaming in Hilbert Space

Marco Tomamichel[1,*]

[1]Centre for Quantum Technologies and National University of Singapore, Singapore

Abstract

Multi-armed bandits are a successful model in the study of reinforcement learning, and bandit algorithms are used, for example, for various recommendation systems. They explore the exploration-exploitation trade-off when we are tasked with maximising a cumulative reward but to do so will need to learn the unknown reward distributions of several arms. In this talk I will extend the bandit framework to the problem of learning properties of quantum systems. As an application, we devise a new optimal online tomography algorithm for pure states that uses measurements biased in the direction of the unknown state and discuss its use for thermodynamic work extraction.

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Invited | 11:05-11:35, December 2, 2024

Quantum Sensing: From Laboratory Innovation to Practical Precision

Rainer H. Dumke[1,*]

[1]Centre for Quantum Technologies, Nanyang Technological University, Singapore

Abstract

Quantum sensing harnesses quantum states unique properties, such as superposition and entanglement, to revolutionize precision measurement. This presentation will overview quantum sensing technologies and their applications, with a special focus on our portable atomic gravimeter, which has shown improved accuracy in large-scale surveys. Field applications and future research directions, including a turn-key portable accelerometer and guided atom interferometry, will also be discussed, emphasizing the transition from laboratory research to practical use and the maturity of quantum sensors for precision measurement.

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ASEAN | 11:35-12:05, December 2, 2024

Molecular Spectroscopy with Scattershot Boson Sampler

Leong Chuan Kwek[1,*]

[1]Centre for Quantum Technologies, National University of Singapore, Nanyang Technological University, Singapore

Abstract

We survey some results in Boson sampling and its application. As an appliaction, we consider scattershot boson sampling using states with squeezed vacuum states coupled to a linear optical network. We show that we can efficiently approximate the molecular vibronic spectra in polynomial time to obtain the minimum value of the target accuracy and the theoretical upper limit of accuracy. We also fabricated a large-scale integrated quantum photonic chip with 16 modes of single-mode squeezed vacuum states and a fully programmable 16-mode interferometer as a versatile simulation platform. Molecular vibronic spectra of formic acid and thymine were accurately simulated using the integrated chip with high reconstructed fidelity.

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Keynote | 14:55-15:40, December 2, 2024

Can Precision Spectroscopy be performed in Ion Coulomb Crystals? - About Tests of Fundamental Physics and Multi-Ion Clocks

Tanja E. Mehlstäubler[1,2,3,*]

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[3]Laboratory of Nano and Quantum Engineering, Schneiderberg 39, 30167 Hannover, Germany

Abstract

Trapped and laser-cooled ions allow for a high degree of control of atomic quantum systems. They are the basis for modern atomic clocks, quantum computers and quantum simulators. In 2012, we proposed to use multiple ions trapped as Coulomb crystals for precision spectroscopy, similar to quantum registers in quantum information. This puts up the challenge to control a nonlinear many-body system with and complex and intriguing dynamics. Our approach paves the way to novel optical frequency standards with ultra-high stability and for applications such as relativistic geodesy and quantum simulators in which complex dynamics becomes accessible with atomic resolution.

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QTRic | 15:40-16:10, December 2, 2024

How Optical Clocks Will Transform Thailand Standard Time?

Piyaphat Phoonthong[1]

[1]National Institute of Metrology (Thailand)

Abstract

We will explain how Ytterbium ion optical clocks can be integrated into Thailand's timekeeping system and distributed using three key synchronization methods. First, the Network Time Protocol (NTP) is widely used for general purposes and provides millisecond-level accuracy over the internet. It is suitable for less critical. Second, the Precision Time Protocol (PTP) offers microsecond-level accuracy and is crucial for fields like telecommunications and finance. This method will ensure higher precision where it is needed. Finally, the White Rabbit Protocol extends PTP to achieve nanosecond-level accuracy, which is necessary for high-precision scientific and industrial applications. This protocol will be used for the most demanding timekeeping needs. By applying these synchronization methods, Thailand can improve its timing infrastructure, making it more precise and reliable. This talk will explain how Ytterbium ion optical clocks, combined with these synchronization techniques, will transform Thailand Standard Time and benefit various sectors in the future. The ultimate goal is a unified time for Thailand.

Invited | 16:30-17:00, December 2, 2024

Nitrogen Vacancy Centres, a Versatile Testbed for Quantum Sensing and Simulations

Soham Pal[1,*]

[1]Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom

Abstract

In recent years, solid-state systems have been at the forefront of quantum technology research. Among these, the Nitrogen vacancy center (NV) in diamond stand out as a remarkable optically active defect because of its unique properties of long coherence times, ease of initialization and readout, and coupling to nearby individual nuclear spins, all at room temperatures, making it an ideal platform for quantum sensing and simulations. In our laboratory, we utilize NVs implanted at varying depths and with difef rent nitrogen concentrations. Our research focuses on nano-scale NMR, in shallow implanted NVs, and manipulation of individual 13C nuclear spin coupled to the NVs, in bulk NV samples, by employing a variety of adiabatic and diabatic dynamical decoupling (DD) sequences.

In my talk, I will present our recent and some ongoing experiments on the implementation of NV-mediated indirect nuclear spin manipulation techniques. We achieve efifcient nuclear spin polarization and arbitrary nuclear spin state preparation using a combination of XY-n, PulsePol, and adiabatic pulse-sequences in bulk diamond NV samples and compare the efifciency of difef rent techniques. With these capabilities we aim to establish this coupled NVs-nuclear spins system as a reliable and robust room temperature testbed for quantum simulations, allowing us to explore quantum thermodynamics and driven many-body systems, towards investigation of quantum devices.

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Contributing | 17:00-17:30, December 2, 2024

Electron Spin Gates in a Scalable Diamond Quantum Register

Timo Joas[1,*], F. Ferlemann[2], R. Sailer[1], P.J. Vetter[1], J. Zhang[1], R. S. Said[1], T. Teraji[3], S. Onoda[4], T. Calarco[2,5,6], G. Genov[1], M. M. Müller[2], F. Jelezko[1,7]

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Abstract

Diamond is a promising platform for quantum information processing as it can host highly coherent qubits. Recent advancements have achieved gate fidelities of nuclear spins that are controlled by a single nitrogen vacancy (NV) electron spin near those of the leading quantum platforms. However, scaling up the register size requires to coherently connect multiple nuclear spin clusters by coupling their central NV electron spins. Entanglement between NV electron spins has been demonstrated, but with a limited fidelity and its error sources have not been characterized. Here, we design and implement a robust two-qubit gate between NV electron spins in diamond and quantify the influence of multiple error sources on the gate performance. Experimentally, we demonstrate a record gate fidelity of $F = 96.0 \pm 2.5\%$ under ambient conditions. Our identification of the dominant errors offers a perspective on the feasibility and challenges for performing error-corrected operations on a future ~100 qubit diamond quantum processor.

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Keynote | 09:00-09:45, December 3, 2024

Quantum non-Gaussian Light and Mechanics

Radim Filip[1,*]

[1]Department of Optics, Palacký University, Olomouc, Czech Republic

Abstract

The bosonic systems currently have revolutionary applications in all pillars of quantum technology. They stimulate further studies of the fundamental features of bosonic states. The talk will present an overview of the theoretical and experimental development of quantum non-Gaussian states of many bosons, their generation, manipulation, detection, identification, scalability, and applications for different experimental platforms: nonlinear optics and cavity QED, microwaves in superconducting circuits, and mechanical motion of trapped ions and nano-oscillators. The particular focus will be on conclusive benchmarking and scalability of quantum non-Gaussian states of light, microwaves and mechanics in recent experiments.

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Invited | 09:45-10:15, December 3, 2024

Super Lasers: Can we achieve the Heisenberg limit for laser coherence?

Howard M. Wiseman[1,*]

[1]Centre for Quantum Dynamics, Griffith University, Australia

Abstract

For more than 60 years, the Schawlow-Townes limit was thought to limit the laser coherence $\mathfrak{C}$ — the number of photons emitted from the laser into the beam in one coherence time — to a scaling $O(\mu^2)$, where μ is the mean number of optical-frequency excitations stored inside the laser. However, recently it has been shown that this is just a standard quantum limit (SQL). The Heisenberg limit — an achievable ultimate limit set by quantum mechanics for the task of producing a beam with the standard properties of a laser beam — is $\mathfrak{C} = O(\mu^4)$, a quadratic enhancement. So far, proposals to demonstrate beyond-SQL scaling of $\mathfrak{C}$ have been limited to circuit QED, at microwave frequencies (i.e. a maser). Here we present the first optical-frequency laser platform that can surpass the Schawlow-Townes scaling: a super-radiant laser in the bad-cavity limit with feedback-controlled collective pumping. We show that the coherence can exhibit a scaling as large as $\mathfrak{C} \sim \mu^{8/3}$, where here $\mu \approx N/2$, where N is the number of super-radiant atoms. Using atoms with an ultranarrow clock transition (mHz), we predict that a laser linewidth (the reciprocal of the coherence time) below 100 μHz could be attainable. This is more than an order of magnitude below standard super-radiant lasers, where the linewidth is limited to the atomic transition width.

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Invited | 10:15-10:45, December 3, 2024

Quantum-optimal Parameter Estimation in Optics and the Example of Source Separation

Nicolas Treps[1,*]

[1]Laboratoire Kastler Brossel, Sorbonne Université, France

Abstract

Quantum optical metrology aims at identifying the ultimate sensitivity bounds for the estimation of parameters encoded into an optical field. In many practical applications, such as imaging, microscopy, and remote sensing, the parameter of interest is encoded not only in the quantum state of the field but also in its spatio-temporal distribution, i.e., in its modal structure. In this context, we propose both a theoretical framework and an experimental approach to derive bounds and perform measurements that are quantum-optimal. We illustrate this with the example of estimating the separation between two incoherent sources, where we experimentally achieve a sensitivity five orders of magnitude beyond the Rayleigh limit. Additionally, we outline a pathway to efficient multi-parameter estimation, with a focus on imaging.

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Invited | 11:00-11:30, December 3, 2024

Optimal Control and Continuously Measured Quantum Systems

Andrew N. Jordan[1,*]

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Abstract

An outstanding problem in continuously monitored quantum systems is how to implement optimal control to achieve certain tasks such as state preparation, entanglement creation or error correction. I will present new results using the most likely path formalism to solve the general optimal control problem and present illustrative examples.

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Invited | 11:30-12:00, December 3, 2024

Agnostic Phase Estimation

David Arvidsson-Shukur[1,*]

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Abstract

Phase estimation is crucial to quantum-information processing. Several quantum algorithms use phase estimation as a subroutine for finding unitary operators' eigenvalues. Furthermore, phase estimation is used in quantum metrology, the field of using quantum systems to probe, measure, and estimate unknown physical parameters. I will tackle the problem of how to measure the strength of a totally unknown unitary. Imagine a unitary rotation generated by a magnetic field. If the direction of the magnetic field is unknown, no strategy with classically separable probes enables optimal measurements of the rotation angle. However, a quantum strategy, relying on entanglement, does. Colleagues and I demonstrate this on a superconducting processor. I will describe how our technique can be used in tasks ranging from sensing to quantum-computer calibration. Further, I will discuss extensions and applications of our agnostic phase-estimation protocol.

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QTRic | 12:00-12:30, December 3, 2024

Enhancing Optoelectronic Properties through Quantum Dot Integration: Interface Engineering and 2D Materials for Semiconductor-based Devices

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Abstract

Quantum dots (QDs) have garnered attention for their unique optoelectronic properties, making them ideal candidates for enhancing device performance in various applications. This talk will focus on leveraging QDs to engineer interfaces in optoelectronic devices and 2D material systems. By integrating QDs at critical interfaces, we demonstrate improved charge transfer, reduced recombination, and enhanced stability, which are crucial for applications in solar cells and photodetectors. Specifically, the talk will highlight the impact of incorporating TiO_2-Graphene Quantum Dot (GQD) nanocomposites at the electron transport layer in Perovskite Solar Cells, resulting in significant efficiency gains. Additionally, we will explore the role of QDs in modulating optoelectronic properties of 2D materials such as MoS_2, showcasing their potential for use in next-generation electronic and photonic devices. This interface engineering approach provides a pathway for developing more efficient, stable, and scalable devices for renewable energy and sensing applications.

Keynote | 09:00-09:45, December 4, 2024

Networks for Modular Quantum Systems

Rodney Van Meter[1,*]

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Abstract

Modular systems were first proposed as a route to scalable quantum computation two decades ago. Key ideas were studied in the 2005-2015 time frame, then a lull ensued as researchers focused on near-term, single-device systems. In the last two years, a burst of activity in the field has resumed, mostly centered on mechanisms for making high-fidelity inter-node entanglement. I will review that recent progress and address the open issues in extending from single links to networks, including presenting our own progress.

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Invited | 09:45-10:15, December 4, 2024

Quantum Optics with Complex Media

Sylvain Gigan[1,*]

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Abstract

Light propagation in complex media has seen a surge of interest in the last decade, with applications ranging from biomedical imaging to sensing or computing. Quantum state propagation and control in complex media remains comparatively in its infancy. I will present the work of our group on shaping photons pairs in multimode fibers, with application ranging from arbitrary linear operator generation, state classification, and quantum machine learning.

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Keynote | 10:35-11:20, December 4, 2024

Advances in Photonic Quantum Computing

Emilien Lavie[1,*], **Anthony Laing**[1,†]

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Abstract

We review basics of photonic quantum computing and illustrate the main research line of our group on quantum simulators with two applications: the simulation of molecular vibrations and of neutrino oscillations. We also present a study of the effect of photon distinguishability on the performance of computing, and report a recent result about a hardware mitigation of this issue. Finally, we highlight progress on distributed quantum computing and information transfer between systems of different dimensions.

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Contributing | 11:20-11:50, December 4, 2024

Synchronizable Hybrid Subsystem Codes

Theerapat Tansuwannont[1,*], **Andrew Nemec**[2,†]

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Abstract

Quantum synchronizable code is a quantum error-correcting code that can correct not only Pauli errors but also errors in block synchronization. In this work, we establish connections between quantum synchronizable codes, subsystem codes, and hybrid codes constructed from the same pair of classical cyclic codes. We also propose a method to construct a synchronizable hybrid subsystem code which can correct both Pauli and synchronization errors, is resilient to gauge errors by virtue of the subsystem structure, and can transmit both classical and quantum information, all at the same time.

Keywords: quantum error-correcting code, synchronizable code, subsystem hybrid code.

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Quantum Communication in Thailand

Poompong Chaiwongkhot[1,*]
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Abstract

There are two major challenges to communication community posted by emerging quantum technology. One is the ability to share quantum states directly between distant quantum computing and sensing nodes. Another is the challenge to information security posted by computation power of quantum computer. Thailand is also in the race to catch up with these new developments. In this talk, we will review of the research and development of devices for quantum communication network. We will start from basic protocols, devices, and components that enable quantum communication all the way to our attempt to improve efficiency and guarantee security of quantum secure communication system.

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POSTER PRESENTATION

S1 : Quantum metrology and sensing

S1-P1

Postselected Quantum Metrology

Flavio Salvati[1], **Wilfred Salmon**[2], **Crispin H.W. Barnes**[1], **David R. M. Arvidsson-Shukur**[3]

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Abstract

Postselected quantum metrology allows detectors to operate at lower intensities without reducing the input rate of quantum information. Until now, the effect of noise on such metrology has not been investigated. I will prove that postselection can always increase the (Fisher) information per output state, even in the presence of strong depolarising noise. The extent of the possible information compression depends on the strength of the noise. I present analytical formulae pinning down this relation. My derivation holds in the case of multi-parameter quantum metrology and postselection by a general filter (i.e., POVM). I design the optimal filter to use in noisy postselected quantum metrology. Finally, I will talk about the relation between our postselected scheme and Weak-Value Amplification.

S1-P2

Fluorescence lifetime measurement of flowing cell in flowcytometry

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Abstract

Flow cytometry is a versatile technology that enables rapid, multi-parametric analysis of single cells in suspension, commonly used in immunology, molecular biology, and cancer research. Conventional flow cytometry relies on intensity-based measurements, such as forward and side scattering, which are often affected by background noise, autofluorescence, and dark counts. To enhance signal quality and measurement accuracy, time-resolved approaches like fluorescence lifetime analysis can be employed, offering sensitivity to environmental factors such as viscosity, pH, and temperature, while remaining independent of dye concentration or excitation intensity. Additionally, fluorescence lifetime analysis allows the discrimination of overlapping fluorescence signals from multiple dyes based on their temporal characteristics.

In this study, we propose a cost-effective flow cytometry design that integrates time-domain fluorescence lifetime measurements with a fast, fit-free analysis algorithm. The system consists of a flow cell chip, dual pumps for hydrodynamic focusing, and an optical setup for excitation and fluorescence detection. To validate the instrument's performance, reference tests with flowing fluorescent dyes and microspheres is conducted.

Potential applications of this system include high-throughput drug screening, monitoring cellular responses to environmental changes, and advanced diagnostics in fields like oncology and immunology, where accurate fluorescence lifetime measurements and the detection of rare events are necessary.

Keywords: fluorescence, time-resolved measurement.

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S1-P3

DC magnetic field sensing with ensemble quantum sensor

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Abstract

Quantum sensing has emerged as a highly promising technology for enhancing classical measurements, and the nitrogen-vacancy (NV) centers in diamond present a strong advantage for quantum sensing in recent years.

Here we present the results on vector magnetometry using ensemble of NV centers using an experimental setup that was adapted from Bucher et. al. We present the real-time measurements of NV center transitions via fast-sweeping optically detected magnetic resonance (ODMR) measurements. From the transitions, we can compute the vector magnetic field to determine the magnitude and the orientation of the magnetic field. WIth our setup, ODMR signals can be captured within few seconds, with the calculated magnetic field magnitude and orientation closely matched the applied values. The setup can be utilized an educational tool for studying funcamental quantum phenomena and further improved for real-time ac sensing applications.

Keywords: Quantum sensing, vector magnetometry, ensemble NV center.

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S1-P4

Development of a Fluorescence Lifetime Spectroscopy System with Cost-Efficient Time-Correlated Photon Counter

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Abstract

Fluorescence lifetime measurement is a versatile tool for studying the dynamics of biological, chemical, and quantum systems. However, commercially available time-correlated single-photon counting (TCSPC) systems are typically very expensive and limited in terms of flexibility. In this study, we developed a fluorescence lifetime imaging microscopy (FLIM) system in a confocal arrangement at room temperature, equipped with a time-correlated single-photon counting module adapted from a time-to-digital converter chip. This system can sustain a count rate of up to 10,000 counts per second with a timing uncertainty of less than 110 ps full width at half maximum. FLIM measurements are obtained by scanning the intensity and probing each point on the sample using the confocal microscope and recording the photon arrival times as histograms. At each position on the sample, the fluorescence lifetime is calculated using the center-of-mass method, which does not require complex curve fitting. The accuracy of this method was validated by imaging fluorescent beads with known lifetimes. Finally, we demonstrate the use of the system for imaging nitrogen-vacancy (NV) defects in diamond, showing that our system and method are suitable for measuring single-photon emitters in the low-photon-count regime. This timing module and calculation method can be used as a standalone upgrade kit for existing microscopes, enabling FLIM measurements in biological research and medical diagnostic applications.

Keywords: nitrogen-vacancy, confocal microscope, fluorescence lifetime, time-to-digital converter.

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S1-P5

Randomized Benchmarking of Quantum Gates in Nitrogen-Vacancy Centers

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Abstract

Color centers in diamond are solid-state systems utilized in quantum technology. A popular example is the nitrogen-vacancy (NV) centers, which serves as a qubit widely used in quantum computing due to its long coherence time and its ability to be manipulated, initialized, and read out optically under ambient conditions. However, a key challenge in quantum computing is achieving quantum gate implementations with low error rates. In this study, we investigate a randomized benchmarking method that provides estimates of computationally relevant errors in quantum gates without relying on the accuracy of state preparation and measurement. This approach offers a reliable estimate of gate fidelity by applying sequences of random quantum gates to the NV center spin.

Keywords: NV centers, Qubit, coherence, randomized benchmarking.

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S1-P6

Towards Holonomic Control of Solid State Qubit Transition using Nitrogen-Vacancy Center in Diamond

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Abstract

As a foundational step in developing quantum computing technology, spin state transitions in diamond with negatively charged nitrogen-vacancy (NV) defects are a promising quantum system for quantum bit (qubit) processing due to their long coherence times under ambient conditions. These systems consist of electron spin interactions with nearby nuclear spins. In this study, we investigate method to control electron and nuclear spin transitions by applying microwave sequences engineered according to the interaction Hamiltonian between spin and photon, resulting in state transitions that are path-independent in the parameter space (holonomic). This approach could improve robustness and yield high-fidelity against quantum noise and accuracy limitation from control system.

Keywords: nitrogen-vacancy, qubit processing, holonomic.

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POSTER PRESENTATION

S2 : Quantum computation, algorithms, and simulation

S2-P7

Characterizing the time dependence of quantum gates

Stanisław Sołtan[1,*], **Daniel Braun**[2], **Alessio Belenchia**[3], **Giovanni Gramegna**[4]

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Abstract

Current state-of-the-art quantum computers exhibit some non-markovian memory effects that make the actual quantum gates deviate from the ideal case. Characterization of such errors is an ongoing challenge. Successfully addressing this challenge could enable the correction of errors or, alternatively, harness these effects to enhance the control of qubits' states and for dissipative-based computation. We analyze the possible generalization of long sequence gate set tomography that takes into account the possible time dependence of quantum gates. A form of time dependence must be assumed and we derived it from the post-markovian master equation. The time dependence of the gates is taken to be explicit in the case of the simplest models of the memory effects. For more complex ones, it is reformulated as the time-independent interaction between the system of interest and auxiliary virtual qubits.

Keywords: quantum gates, quantum tomography, non-markovian effects.

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S2-P10

Electron Spin Echo Envelope Modulation for Electron Package Spin Control in a Polymer-Based Quantum Math Engine

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Abstract

We developed a spin control mechanism specifically tailored for packaged current within polymers, combined with resonator and cavity materials, to create a few quantum qubits, termed the Quantum Math Engine (QME). The QME retains the full properties of quantum superposition and entanglement. We provide a detailed analysis of the theoretical principles, integration with the spin control package, and enhancements to the versatility required for a Quantum Operation Node. The completed tasks include a 1st layer ring resonator antenna system, a 1024-bit QAM/CDMA codec, and the ability to define the virtual layer depth that occurs on the polymer tube.

Keywords: ESEEM, package electron spin, Polymer-Based Quantum Qubits.

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S2-P12

Quantum Algorithms with Trapped-Ion quDits

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Abstract

In this work, we present the latest experimental results on the implementation of quantum algorithms using trapped-ion qubits. We used ytterbium ions to experimentally demonstrate an improved multi-qubit Toffoli gate using qudits. By using dual optical-microwave encoding and global microwave control, we were able to execute a qutrit-based decomposition with a linear number of entangling gates. On the example of the Grover's algorithm, which includes a multi-qubit Toffoli gate, as well as the Bernstein-Vazirani algorithm, we achieved a decrease in the average error of these algorithms by using qudits. These results demonstrate the benefits of using qudits in NISQ devices.

Keywords: Qudits, trapped-ions, quantum algorithms.

S2-P11

Grasp All, Find All: Quantum Walk Search with Multiple Oracles

Mansur Ziiatdinov[1,*]

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Abstract

Quantum search is ubiquitous in quantum computing. Started as an unstructured database search [1], modifications and generalizations of quantum search are used in various algorithms, from pattern matching [2] to exponential-time dynamic programming [3]. The goal of quantum search is defined by an oracle gate, which marks the desired value. While some applications use the quantum search with the single oracle, others (such as batch training in machine learning) are better described with multiple oracles. We extend the quantum walk search algorithm of Krovi et al. [4] to multiple oracles.

Keywords: quantum walk multiple oracles.

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[1] L. K. Grover, in *Proc. twenty-eighth Annu. ACM Symp. Theory Comput. - STOC '96* (1996), pp. 212–219.
[2] A. Montanaro., Algorithmica **77**,16 (2017)
[3] A. Ambainis *et al.*, in *Proceedings of the Thirtieth Annual ACM-SIAM Symposium on Discrete Algorithms*, (2019) pp. 1783–1793
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S2-P13

Strategic Codes: The Universal Spatio-Temporal Framework for Quantum Error-Correction

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Abstract

The novel dynamical quantum error-correcting code (QECC) paradigm established new ways to achieve a noise-resilient temporal encoding of quantum information through sequential quantum operations, offering more resource-efficient QECCs. Despite these advances, our understanding of the most general way error-correction can be performed spatio-temporally remains limited without a unified framework. We bridge this gap by proposing the "strategic code" framework, a general QECC model incorporating all existing and all physically plausible QECCs, as well as the most general correlated (non-Markovian) noise. Within the framework we establish necessary and sufficient error-correction conditions and propose an optimization-theoretic approach to construct a strategic code that approximately recovers the encoded information.

Keywords: Quantum error-correction, Dynamical quantum error-correction, Quantum process.

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S2-P15

Measurement-based uncomputation of quantum circuits for modular arithmetic (and applications)

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Abstract

Measurement-based uncomputation (MBU) is used to perform probabilistic uncomputation of quantum circuits. We formalize this technique and show applications to modular arithmetic. We present formal statements for several variations of non-modular addition, subtraction and comparison circuits. This addresses gaps in the current literature, where some variants were unexplored. We then extend our results to modular versions thereof. Using MBU, we reduce the Toffoli count and depth by 10% to 25% for various modular adders in the literature. Our results have the potential to improve other arithmetic circuits, with applications in cryptanalysis.

Keywords: quantum circuit optimization.

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S2-P16

Half Adder and Full Adder Circuit Implementation using Quantum Photonics

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Abstract

Quantum computing promises to revolutionize various computational tasks by harnessing the principles of quantum mechanics. In classical computation, addition is a fundamental operation, and its quantum counterpart, the quantum adder, plays a pivotal role in quantum arithmetic. The quantum adder starts by preparing q-modes representing the input binary numbers for addition, as well as an additional q-mode for the carry input. We initialize these q-modes with precise quantum states corresponding to the input values. We built relationships between discrete and continuous variable gates. We built both quantum adder circuit using two subcircuits, the Toffoli gate and the CNOT gate.

Keywords: Toffoli, CNOT, q-mode.

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S2-P18

Quantifying resource of pure and mixed states

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Abstract

The resource such as entanglement or nonclassicality of a quantum state is of fundamental importance for quantum information applications. However quantification of the resource for a given quantum state is not easy. We demonstrate a practical method for calculating the lower and up bounds of robustness of resource. In many cases, the lower and up bounds coincide with each other, thus the robustness of resource can be determined. Several examples are provided to illustrate the details.

S2-P21

Estimating parameters of transmon-qubit systems using Bayesian statistics and sequential Monte Carlo method

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Abstract

An effective protocol for quantum feedback control requires knowing the transmon qubit's state. With data from continuous weak measurement, we can use Bayesian statistics and sequential Monte Carlo methods to estimate the parameters of the qubit. Our work demonstrates simultaneous estimation of six parameters of transmon-qubit experiments using signals from continuous dispersive measurements. We compared our estimated values against independently calibrated ones and found that our method can extract time-dependent information of the parameters.

Keywords: Parameter Estimation, Sequential Monte Carlo Method, Bayesian Statistics.

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S2-P22

The Simulation of the Three-dimensional Optical Tweezer Pattern

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Abstract

Optical tweezers are essential tools for manipulating the positions of neutral atoms in arbitrary geometries. However, most research designs tweezer patterns in two dimensions, limiting the control of atoms in other focal plane layers. In this work, we simulate three-dimensional optical tweezer arrays using a modulated phase mask with a Gaussian beam profile. The phase masks are generated using two methods: the direct phase addition and the heuristics-weighted Gerchberg-Saxton algorithm. We analyze the characteristics of a 3x3 optical tweezer array using the angular spectrum method, with each column corresponding to a different layer. The direct phase addition provides better homogeneity of tweezer intensity on the desired plane compared to another method. This technique will be beneficial for manipulating the single atoms in three dimensions for use in quantum simulations and quantum computing applications.

Keywords: Optical tweezers, Fourier optics.

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S2-P23

Aberration correction of optical dipole-traps array utilizing phase-modulated Holographic technique

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Abstract

Optical dipole traps are used to form atom arrays, which are important for quantum experiments. These arrays allow for precise control of quantum states and are useful for quantum simulations due to their flexible setups and ability to control individual atoms. However, creating dipole-trap arrays inside a vacuum chamber is challenging. The laser beam used to form the traps must pass through several optical components, like vacuum windows and high-numerical-aperture lenses. These components can distort the laser beam and cause unwanted changes, called aberrations. To solve this problem, we use a holographic phase pattern to correct the aberration. The phase pattern is applied using a Spatial Light Modulator (SLM) to generate the optical dipole trap array. We examine how each optical component affects the beam and causes aberrations, then develop methods to correct this aberration. This is done by modified the phase pattern and using feedback to improve the trap array. The Gerchberg–Saxton algorithm helps us correct the distortions and restore the intended trap pattern. This method allows us to prepare precise optical dipole trap arrays, which are essential for future experiments with cold single-atom arrays in a vacuum.

Keywords: Optical dipole trap, Spatial Light Modulator, Holographic technique.

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S2-P24

Spatial entanglement between two quantum walkers with exchange symmetric coins

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Abstract

We investigate how the symmetries associated with the initial setting and the measurement outcome of the coins affect the dynamics of the spatial entanglement between the two identical quantum walkers. For the antisymmetric initial state, we demonstrate that the spatial entanglement between the two walkers is always constant at maximum for every possible symmetric outcome of the coins, while the antisymmetric outcome is oscillating with a period (T) that is inversely proportional to the coin operator parameter (θ). Furthermore, when the initial state is symmetric and/or the post-selected results lack symmetry, we observe dampening in the spatial entanglement. Our findings yield essential insights for prospective application in quantum technology by revealing how symmetries affect the dynamics of entanglement in quantum walks.

Keywords: Quantum walk, Spatial entanglement, Symmetry.

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S2-P25

Design of Magnetic Transport and Trap for Cold Atom Preparation on Chip Assembly

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Abstract

We study the trapping patterns of rubidium atoms on atom chip components. To trap rubidium atoms using magnetic field generated from the atom chip, the atoms must be sufficiently cooled to be confined by a magnetic field. Initially, the cooled rubidium atoms are prepared using the optical magneto-optical trap (MOT), reaching temperatures in the hundreds of micro-Kelvins. Subsequently, we use optical molasses to achieve rubidium atoms with a temperature of approximately 30 micro-Kelvins. At this temperature, atoms can be trapped using a magnetic field with a gradient of 20G/cm. Since the atom chip is placed outside a thick glass cell, the atoms need to be transported using a magnetic field for a distance of approximately 2 cm to bring the atoms close to the atom chip's surface (about 7 mm away). The magnetic field values are obtained from simulations using COMSOL Multiphysics. Afterward, the efficiency of the atom trapping by the magnetic field generated by the atom chip is tested by assuming that the distribution of atom at thermal equilibrium is Gaussian. The simulation results indicate that we can create a magnetic field that can be adjusted as desired and trap atoms at a distance of 7 millimeters for 100 milliseconds with an efficiency of 60%. In the experimental part, we aimed to achieve the preparation of cold atoms and to measure the temperature to reach the expected temperature of 30 micro-Kelvin under optical molasses state. Currently, the lowest temperature we can achieve for atoms in our trap is 82.5 micro-Kelvin.

Keywords: Magneto-optical trap, COMSOL Multiphysics, Atom chip.

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S2-P26

Inverse design of reconfigurable optical circuits using complex scattering processes

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Abstract

We demonstrated how to construct a reconfigurable optical circuit encoded in d transverse spatial modes by harnessing complex scattering processes of a multimode fiber. The optical apparatus was used for d-dimensional entanglement certification with $d = \{2, 3, 5, 7\}$.

Keywords: Optical circuits, High-dimensional entanglement, Unitary decomposition.

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POSTER PRESENTATION

S3 : Quantum information theory

S3-P1

Towards practical quantum error correction with holographic codes

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Abstract

Holographic quantum error-correcting codes are models of bulk/boundary dualities, where a higher-dimensional, hyperbolic bulk geometry is associated with the code's logical degrees of freedom. Beyond modeling interesting physics, including aspects of quantum gravity, these codes have recently been studied from the perspective of practical error correction. In this overview of our recent work, we show that a new class of holographic subsystem codes based on tensor networks have competitive rate and distance scaling and perform well under erasure, biased, and depolarizing errors. This class includes simple qubit codes that could be promising candidates for near-term implementation on quantum devices.

Keywords: Quantum Error Correction, Tensor Network Codes.

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S3-P3

Quantum State Smoothing does not Require a Second Observer

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Abstract

Quantum State Smoothing is a technique that estimates the state of an open quantum system based on measurement outcomes both prior and posterior to the time of estimation. However, to use this technique requires one to assume how the environment effectively measured any information your measurement missed [1]. In this work, we approach smoothing from the point of view of Bayesian retrodiction. By adapting the Petz recovery map [2] to utilize the outcomes after the estimation time, we derive an alternative smoothed quantum state that does not rely on how the environment measures the remaining information. Furthermore, not only does this state share key properties one would expect of a smoothed quantum state, but it also provides insight into how the smoothing of Ref.[1] works.

Keywords: Open Quantum Systems, Continuous Quantum Measurement, Quantum Retrodiction.

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S3-P4

Cumulant-based quantum relative Rényi entropy

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Abstract

We propose a new mathematical definition of quantum relative Rényi entropy based on a path-integral-like formulation, along with an information-theoretic interpretation of the Rényi parameter. While previously proposed definitions lack clear motivational foundations, our expression naturally emerges from the statistical concept of cumulant-generating functions. We also examine the complex action that arises from our formulation, analyzing its equations of motion and associated statistics in a qubit scenario.

S3-P5

Nonlinear bosonic Maxwell's demon

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Abstract

The concept of Maxwells demon, proposed in classical physics as a means to extract work from a thermodynamics system beyond the constraints set by the second law of thermodynamics, has since been extended to modern quantum physics. Realization of the quantum Maxwells demon remains of actual interest given the potential of continuous-variable systems in quantum thermodynamics and current experimental opportunities. We propose a quantum Maxwells demon method, based on a Jaynes-Cummings two-level system, for subtracting bosonic energy inferred from successful measurements of excited qubits after linear and nonlinear interactions. The effect of these subtractions can suppress the tails of bosonic noise better than the linear interactions alone. The system statistics reaches an out-of-equilibrium state, becoming much closer to Poissonian distributions as indicated by the mean-to-noise ratio. The inclusion of a few additional optimal nonlinear subtractions can improve the success rate to ten times higher than the linear scheme, making the method significantly more efficient in exciting hundreds of qubits.

Keywords: Quantum Maxwell's demon, Nonlinear interaction, Jaynes-Cummings.

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POSTER PRESENTATION

S4 : Quantum communication, networks, and cryptography

S4-P4

A study on the construction of an open user testbed for commercialize product using Quantum technology

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Abstract

Recently, With the rise of AI and big data technologies, sensitive personal information is transmitted through the Internet, and the importance of communication security is highlighted, various devices, parts, and equipment that apply quantum technology are being developed. However, there is no case of building an open Quantum testbed network to create a virtuous cycle ecosystem that can efficiently commercialize these results to companies. This paper is a study on a case of building a demonstration network that can perform short-distance/long-distance tests of Quantum internet, Quantum sensors, Quantum technology application devices, components, and QKD equipment in industry-academia-research.

Keywords: QKD, Quantum internet, Open Quantum Testbed.

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S4-P9

Physical Random Number Generator on Photonic Chip

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Abstract

We introduce a physical random number generator (RNG) utilizing a silicon nitride photonic chip. Using an 810 nm attenuated laser, photons are directed into a multi-mode interference reflector, a type of beam splitter commonly employed in integrated photonic chips. Which-path measurement of photons using a single-photon avalanche diode in each output port provides raw bits. To address potential biases from the system, a pairwise XOR is applied to extract random bits. Our RNG successfully generates random bits at a rate of 83 Kilobits per second. These random numbers have undergone testing using the NIST statistics tests.

Keywords: Random number generator, Pairwise XOR extraction.

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POSTER PRESENTATION

S5 : Quantum technologies (optics, NMR, solid-state, etc.)

S5-P1

Exponentially faster preparation of quantum dimers via driven-dissipative stabilization

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Abstract

Despite the many proposals to use dissipation as a resource to prepare long-lived entangled states, the speed of such entanglement generation is usually limited by the requirement of perturbatively small driving strengths. We propose a new scheme to rapidly generate manybody entanglement between multiple spins coupled to a 1D bath stabilised by the dissipation into the bath. Our work stands in contrast to the current well known steady state protocols for entanglement generation in spins coupled to 1D baths that take a prohibitively long time, and exhibits a speedup over state-of-the-art protocols by several orders of magnitude.

Keywords: Chiral Quantum Optics, Quantum Control, Open Systems.

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S5-P2

The impact of magnetic field on nitrogen-vacancy center technology - the case of rabi oscillation

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Abstract

Quantum computing, leveraging the principles of quantum mechanics, promises significant advancements over classical computing in solving certain complex problems. This paper presents observations and analyses from a series of fundamental quantum experiments conducted using the a Diamond Quantum Computer. The primary objective is to explore the quantum properties of nitrogen-vacancy (NV) centers in diamond, which serve as qubits in quantum computing. We present the results of the experiments conducted on Rabi Oscillation and we observe the impact of magnetic field on the coherent oscillation of a quantum system's state between two levels. These experiments are crucial for the understanding of the dynamics of NV centers in quantum computing.

Keywords: Nitrogen-vacancy (NV) centers, Rabi Osillation, Magnetic Field.

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S5-P3

Engineering light-matter coupling in superconducting circuits with van der Waals heterostructures

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Abstract

Over the past few decades, the developments of weak and strong coupling regimes in light-matter interactions have provided exquisite controls over quantum systems and underpinned applications of modern quantum technologies in areas like computation, communication, and metrology. Experiments pushing light-matter interactions into the ultrastrong coupling regime could lead to enhanced quantum information processing protocols such as faster logic operations between multiple qubits. Previous demonstrations of ultrastrong coupling with superconducting transmon qubits relied on the vacuum-gap architecture that require delicate fabrication processes. Here, I will discuss the efforts to realize ultrastrong coupling in superconducting circuits with van der Waals heterostructures – potentially offering an alternative platform to explore multi-qubit dynamics in the ultrastrong coupling regime.

S5-P4

Spin Seebeck effect in La1-xSrxMnO3/Yttrium Iron Garnet composites synthesized via co-precipitation: Experimental and theoretical insights using VASP

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Abstract

This study investigates the Spin Seebeck Effect (SSE) in La1-xSrxMnO3 (LSMO)/Yttrium Iron Garnet (YIG) composites synthesized via the co-precipitation method. Structural characterization confirms high-quality LSMO/YIG. Density functional theory (DFT) simulations using VASP provide insights into the electronic structures and magnetic interactions of LSMO and YIG. The SSE is measured via the inverse spin Hall effect, demonstrating efficient spin current generation. The findings are significant for quantum technologies, where spin currents play a key role in developing low-energy, quantum-based spintronic devices, offering new pathways for information processing, thermal management, and quantum computing.

Keywords: Spin Seebeck Effect (SSE), Density functional theory (DFT), LSMO/YIG.

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S5-P5

Investigation of ferroelectric BNT barrier introduction in YBCO|BNT|YBCO Josephson Junctions and its impact on superconducting and vortex dynamics behavior

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Abstract

Our research investigates the interface between a traditional superconductor and a ferroelectric insulator in a YBCO|BNT|YBCO junction fabricated via pulsed laser deposition. We study the temperature-dependent normal coherence length of the BNT barrier, revealing dynamic superconducting properties. Magnetic field- induced modulation of critical current in the junction exhibits a Fraunhofer-like pattern, highlighting the interplay between magnetic fields and critical current. Electrical characterization shows a critical current of 0.65 μA at 50 K with RSJ behavior at higher biases. STM experiments explore vortex cores, deepening our understanding of superconducting behavior and future applications in quantum electronics.

Keywords: Superconductor-ferroelectric interface, Josephson junction, Critical current modulation.

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S5-P6

Spin current diffusion depends on the ultra-thin iron film thickness by the Spin-Seebeck effect

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Abstract

The spin current is generated from ferromagnetic (Fe)/nonmagnetic (Pt) bilayer thin films on SiO2 substrate by spin Seebeck effect (SSE) with inverse spin Hall effect (ISHE). The iron can originate pure spin current through temperature gradient into 0 – 30K at perpendicular to the Fe/Pt interface. The heavy nonmagnetic metal as Pt converse spin-to-charge as voltage via the ISHE. The thickness dependence of the iron layer demonstrates the spin-diffusion length, which is between 3 nm and 20 nm by DC magnetron sputtering. Our results present the high voltage at the 3 nm thickness by hysteresis loop on 500 Oe magnetic field.

Keywords: Diffusion length, Iron thin film, Spin-Seebeck effect (SSE).

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S5-P7

SSE voltage enhancement in Si/YIG/Co, Fe spin Hall thermopiles

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Abstract

Spin-Hall thermopiles have been proposed to enhance the SSE, but Pt for spin detection is costly and limits scalability. We present a cost-effective spin Hall thermopile using Co and Fe with opposite spin Hall angles. Fabricated on a sputter-coated YIG substrate as the spin injector, and thermally evaporated Co/Fe strips for spin detection, the [YIG/Co, Fe] thermopile shows a significant enhancement in spin voltage due to additive spin contributions from the ferromagnets and the ANE effect. This YIG/Co, Fe thermopile offers a cheaper alternative to Pt-based thermopiles, enabling potential large-scale thermoelectric generators.

Keywords: Spin Seebeck effect, Spin-Hall thermopile, Inverse spin Hall effect, Pure spin current, Spin Hall effect.

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S5-P8

Observation of Spin Thermoelectric in Si/CoCrNiFe for Spin Seebeck Effect

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Abstract

The study of spin-dependent thermoelectric properties in advanced materials is essential for developing efficient energy conversion systems. One key phenomenon in this area is spin Seebeck effect (SSE), which involves generating of spin current from heat. Medium entropy alloys (MEAs) show promising potential by exceptional thermal stability. In this study, CoCrNiFe films were deposited on Si and SiO_2 substrates via sputtering to examine their spin- dependent thermal properties. To assess their performance in spin thermoelectric applications, CoCrNiFe films of varying thicknesses (4 nm, 9 nm, 12 nm, 15nm, 18nm, 21nm as well as 94nm) were prepared. The magnetic properties were analyzed using Vibrating Sample Magnetometry (VSM), while X-ray Diffraction (XRD), Transmission Electron Microscopy (TEM), and Scanning Electron Microscopy (SEM) were employed for morphological and structural characterization. Temperature and angle-dependent voltage measurements revealed a value of approximately 1400 μV for the 12 nm thick film

S5-P9

The thickness dependent of Si/Fe3O4/Pt thin film for spin Seebeck effect by sputtering technique

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Abstract

The field of spintronic is focusing on generation, detection and manipulation of pure spin current. The spin Seebeck effect (SSE) is the one branch of this which is referred as the generation of pure spin current by temperature. We propose the preparation of Si/Fe3O4/Pt thin film by sputtering technique in varying thickness for SSE observation. The ion of Fe3O4 target was coated on Si-Wafer by RF-power supply of 100 Watt in Ar atmosphere of 5 mTorr pressure with operating time of 90 min,180 min and 270 min for 60 nm, 120 nm and 180 nm thickness, respectively. Then the platinum (Pt) of 15 nm thickness with 66 sec operation time was coated on top of Fe3O4 film. The samples were annealed at 800 °C for 2 hr stabilization. The crystal structure, magnetic properties and film thickness were observed by x-ray diffraction (XRD), vibration sample magnetometer (VSM) and scanning electron microscopy (SEM), respectively. For SSE determined, the magnetic and temperature dependent were studied. The results shown that the Fe3O4 film was exhibited the polycrystalline with ferromagnetic behavior. The film surface is shown much smooth after annealed. The Fe3O4 film of 60 nm and 120 nm thickness is not found the generation of pure spin current while the Fe3O4 of 180 nm thickness is shown the spin current generation. The spin Seebeck coefficient of Fe3O4 (180nm) is detected about 0.018 μV/K. We conclude that the preparation of Si/Fe3O4/Pt thin film by sputtering technique can be used to study SSE phenomenon. The Fe3O4 film thickness which is used for spin injection need to be thick more than 180 nm.

Keywords: Spin Seebeck effect, spintronic, inverse spin Hall effect, sputtering technique, temperature annealing.

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S5-P10

Effect of Spin Seebeck effect on Ni slant nanorods thin films prepared by DC magnetron sputtering

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Abstract

In this research, we investigations the Spin Seebeck Effect (SSE) and show the spin current generated from magnetic materials such as ferromagnetic (FM) in a Nickel slant-nanorods (Ni SNRs) thin films were deposited by DC magnetron sputtering with oblique angle deposition (OAD) technique on Si and SiO_2 substrate in varying thickness at 20, 50, 100, and 200 nm. For SSE determined, we use temperature gradient (ΔT) range 0 – 30K perpendicular to the Ni SNRs interface. Surface and morphology were observed by field-emission scanning electron microscope (FE-SEM) however, determined thicknesses of Ni SNRs at lower thickness show imperfect nanorods structure. The crystalline structure was determined by the grazing-incidence x-ray diffraction (GI-XRD) which revealed strong peaks corresponding to the (111), (200), and (220) planes.

Keywords: Nickel slant nanorod film, DC magnetron sputtering, oblique angle deposition (OAD), Spin-Seebeck effect (SSE).

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S5-P11

The influence of temperature annealing in Si/Y3Fe5O12/Pt by sputtering technique for spin Seebeck effect.

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Abstract

The generation of pure spin current (J_s) by thermal is known as spin Seebeck effect (SSE). This work, we focus on the preparation of Y3Fe5O12 (YIG) spin injector insulation by sputtering technique as a function of temperature annealing. The results found that the YIG is formed in polycrystalline structure as temperature annealing upper than 700 °C otherwise it is an amorphous phase. The polycrystalline structure of YIG is shown the ferromagnetic while the amorphous phase is demonstrated the super paramagnetic. As an influence of temperature annealing to sample structure, the spin conversion is being observed in temperature above 700 °C in which the signal is maximum at 750 °C and then it is decreased. The decreasing signal at higher temperature comes from the Pt film and was destroyed by temperature annealing as seen in the SEM image and the increasing resistance. In conclusion, this work suggests that the preparation of YIG by sputtering technique is needed to be annealing about 750 °C which is found the highest spin conversion.

Keywords: Spin Seebeck effect, spintronic, inverse spin Hall effect, Yttrium iron garnet (YIG), Platinum (Pt), sputtering technique, temperature annealing.

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Emilien Lavie	University of Bristol, United Kingdom
Ivan Deutsch	University of New Mexico, United States
Mile Gu	Nanyang Technological University, Singapore
Radim Filip	Palacky University, Czech Republic
Rodney Van Meter	Keio University, Japan
Tanja E. Mehlstäubler	Leibniz Universität Hannover, Germany

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Andrew N. Jordan	Chapman University, United States
David Arvidsson Shukur	Hitachi Cambridge Laboratory, United Kingdom
Francesco Buscemi	Nagoya University, Japan
Howard M. Wiseman	Griffith University, Australia
Jayne Thompson	Institute of High Performance Computing, A*STAR, Singapore
Marco Tomamichel	Centre for Quantum Technologies, National University of Singapore, Singapore
Nicolas Treps	Laboratoire Kastler Brossel, Sorbonne Université, France
Rainer H. Dumke	Centre for Quantum Technologies, Nanyang Technological University, Singapore
Soham Pal	Cavendish Laboratory, University of Cambridge, United Kingdom
Sylvain Gigan	Laboratoire Kastler Brossel, Sorbonne Université, France

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Hishamuddin Zainuddin	Xiamen University Malaysia, Malaysia
Leong Chuan Kwek	Centre for Quantum Technologies, National University of Singapore, Nanyang Technological University, Singapore
Yung Szen Yap	Universiti Teknologi Malaysia, Malaysia

QTRic Speakers

Name	Affiliation
Nithiwadee Thaicharoen	Chiang Mai University
Piyaphat Phoonthong	National Institute of Metrology (Thailand)
Poompong Chaiwongkhot	Quantum Technology Foundation (Thailand) QTFT
Supanut Thanasilp	Chulalongkorn University
Sukrit Sucharitakul	Chiang Mai University

QTFT Speakers

Name	Affiliation
Gun Pinyo	Quantum Technology Foundation (Thailand) QTFT
Panithi Suwanno	Quantum Technology Foundation (Thailand) QTFT

Contributing Speakers

Name	Affiliation
Theerapat Tansuwannont	Center for Quantum Information and Quantum Biology, Osaka University
Timo Joas	Universität Ulm, Germany

Poster Presenters

Name	Affiliation
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Anastasiia Nikolaeva	International Center for Quantum Optics & Quantum Technologies Limited Liability Company, Russia
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