KOBIT 8

ÖNEMLİ TARİHLER

Konferans tarihleri: 25-26 Nisan, 2024

Özet gönderim son tarihi: 15 Mart, 2024

Kayıtlar için son tarih: 7 Nisan, 2024

TÜBİTAK

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Önsöz

2016 yılından beri her sene düzenlenmekte olan Kuantum Optiği ve Bilişim Toplantısı (KOBİT), hem yurtiçinde hem yurtdışında kuantum optik alanında çalışmakta olan değerli araştırmacıları, öğrencileri ve bu alanda uzmanlaşmış özel sektör firmalarını bir araya getirmeyi amaçlayan, kar amacı gütmeyen bir oluşumdur. 2024 yılında KOBİT-8 adıyla yapılacak olan toplantının 25-26 Nisan tarihlerinde TÜBİTAK Gebze Yerleşkesi'nde düzenlenmektedir.

Bu sene gerçekleştirilecek olan toplantının ana konuşmacısı Prof. Dr. İrfan Siddiqi, Berkeley Üniversitesi Fizik Bölümü'nde kuantum fiziği, yoğun madde fiziği ve malzeme fiziği alanlarında çalışmalar gerçekleştiren "Quantum Nanoelectronics" laboratuvarının kurucusu ve yürütücüsü olarak görev yapmaktadır. 2 gün boyunca 4 farklı oturumda gerçekleşecek olan toplantıda, ana konuşmacı ve çağrılı konuşmacıların vereceği sözlü sunumların yanı sıra endüstri oturumu ile başvuran öğrencilerden seçilmiş posterlerin sergilendiği bir oturum da planlanmıştır.

Bütün katılımcılara katkıları için teşekkür eder, iyi bir toplantı geçirmenizi dileriz.

Foreword

Quantum Optics and Informatics Meeting (KOBIT), which has been held every year since 2016, is a non-profit organization that aims to bring together valuable researchers, students and private sector companies specialized in this field, working in the field of quantum optics both at home and abroad. The meeting, which will be held in 2024 under the name KOBT-8 at TÜBİTAK Gebze Campus on 25-26 April.

The main speaker of the meeting to be held this year is Prof. Dr. İrfan Siddiqi serves as the founder and director of the "Quantum Nanoelectronics" laboratory, which carries out studies in the fields of quantum physics, condensed matter physics and material physics at the Department of Physics at Berkeley University. The meeting, which will be held in 4 different sessions over 2 days, is planned to include oral presentations by the main speaker and invited speakers, as well as a session where posters selected from the students who applied through the industry session will be exhibited.

We thank all participants for their contributions and wish you a good meeting.

Program

Time	Day 1
9:30-11:00	**Opening**
11:00-11:15	**Zafer Gedik** Alexander Klyachko'yu anma konuşması
11:15-11:45	**Break**
1st Session	**Chair: Kadir Durak**
11:45-12:45	**Irfan Siddiqi** The Third Quantum Revolution
12:45-13:15	**Vira Besaga (online)** Towards remote polarimetry and polarization based classification using entangled photons
13:15-14:15	**Lunch Break**
14:15-16:45	**Poster presentations**
21:00-22:00	**Popüler Konuşma (online)** **Onur Pusuluk** Biochemical phenomena from the perspective of quantum information science
Time	**Industrial Talks**
2nd Session	**Chair: Özgür E. Müstecaplıoğlu**
14:15-14:20	**Özgür E. Müstecaplıoğlu** Openning and Perspectives on the State of the art and future of quantum industry
14:20-14:40	**Tezgül Coşkun** Enhancing Digital Metrology by Employing New Generation Josephson Voltage Standards as Reference
14:40-15:00	**Mehmet Çelik** Development of an Sr Optical Lattice Clock at TUBITAK UME
15:00-15:20	**Özlem Salehi Köken** Quantum Computing for Life Sciences
15:20-15:50	**Break**
3rd Session	**Chair: Alpan Bek**
15:50-16:10	**Mehmet C. Onbaşlı** 2D Quantum Materials for Single Photon Detection
16:10-16:30	**Buse Bilgin** Mobile operators in the quantum age: the next big step in mobile technology

Time	Day 2
1st Session	**Chair: Zafer Gedik**
09:30-10:00	**Lianao Wu (online)** Introduction to self-protected quantum algorithms: quantum simulations
10:00-10:30	**Marco Cattaneo** Collision models to simulate the Markovian dynamics of multipartite quantum systems
10:30-10:45	**Bilal Cantürk** Unifying Stochastic Processes and Quantum Operations
10:45-11:00	**Gökhan Torun** Quantum Resources: Pinnacle of Quantum Superposition
11:00-11:30	**Break**
2nd Session	**Chair: Cem Yüce & Onur Pusuluk**
11:30-12:00	**O. Barış Malcıoğlu** Using Quantum Computer assistance to scale Quantum Discord calculation for nano materials
12:00-12:30	**Orkun Hasekioğlu** Neuromorphic computing and Superconducting Single Photon Nanowire Detector (SNSPD) applications
12:30-13:00	**Yusuf Karlı** Advanced Excitation Techniques for Quantum Dots
13:00-14:15	**Lunch Break**
3rd Session	**Chair: Mehmet Emre Taşgın**
14:15-14:45	**Fabrizio Piacentini** Single-pair measurement of the Bell parameter: testing novel nonlocality bounds while certifying entanglement without destroying it
14:45-15:15	**Kübra Yeter-Aydeniz (online)** Medical Image Generation Using Quantum Generative Adversarial Networks
15:15-15:30	**Dario Ferraro** Fast charging of Dicke Quantum Batteries
15:30-16:00	**Break**
4th Session	**Chair: Onur Pusuluk**
16:00-16:30	**Ceren Dağ (online)** Engineering Topology in Graphene with Chiral Cavities
16:30-16:45	**Ekrem Talha Güldeste** Wavelet-based magnetometry enhancement of NV centers in diamonds

Konuşmalar / Talks

The Third Quantum Revolution

İrfan Siddiqi

The first quantum revolution brought us a theory that describes the physical world around us with exquisite precision, with no known violations. Ironically, this precision comes with some additional baggage: the theory permits the existence of a host of complex, delicate entangled states of the physical world—the existence of these states and their use in secure communication systems is hallmark of the second quantum revolution. The debate of whether quantum entanglement can exist at large scale is at the heart of the third quantum revolution where we seek to harness entanglement for computation. Quantum processors with of order 100 qubits based on superconducting circuitry have recently demonstrated computing power on par with the most advanced classical supercomputers for select problems. Current hardware is, however, prone to errors from materials defects, imperfect control systems, and the leakage of quantum information into unwanted modes in the solid-state. I will describe the major decoherence pathways present in state-of-the-art superconducting quantum processors, illustrate techniques to maximize the computing power of imperfect qubits, and introduce including new architectures using qutrits and ququarts.

Bio:

Irfan Siddiqi is the head of the Physics Department at UC Berkeley where he is the Douglas Giancoli Chair Professor. He is also a professor of Electrical Engineering and Computer Science, and a Faculty Scientist at Lawrence Berkeley National Laboratory. His research group focuses on the development of advanced superconducting circuits for quantum information processing, including computation and metrology. Irfan is also the director of the Advanced Quantum Testbed at LBNL, which develops and operates full-stack quantum computing platforms based on superconducting qubits. He is known for key contributions to quantum measurement science, including real time observations of wavefunction collapse, tests of the Heisenberg uncertainty principle, quantum feedback, and the development of a range of microwave frequency, quantum noise limited amplifiers and detectors. Irfan is a fellow of the American Physical Society, and the recipient of its George E. Valley prize and Joseph F. Keithley Award. He is also a recipient of the University of California Berkeley Distinguished Teaching Award, the university’s highest award for commitment to pedagogy.

Towards remote polarimetry and polarization based classification using entangled photons

Vira R. Besaga
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Polarization of light is widely used to probe sample's properties within the well-acknowledged Stokes and Mueller polarimetry for a broad range of applications. Enrichment of the technique via utilization of the quantum states of light promises enhancement in the measurement precision, realization of spatially and spectrally separated probing and analysis channels, as well as revealing potentially new information about the object under study. Here, we report on our recent activities towards establishing practical quantum polarimetry of subtle samples using polarization-entangled photon pairs. For the case when the complete characterization is redundant, we present our approach for polarization based differentiation which allows for decreasing the number of measurements per sample down to just two. Moreover, this method implies realization of only one fixed polarization projection after the sample while the required projective analysis is performed in a remote channel where photons never interact with the sample.

Collision models to simulate the Markovian dynamics of multipartite quantum systems

Marco Cattaneo

Collision models have become one of the most successful formalisms in open quantum systems, being widely employed to study e.g. thermodynamic processes or quantum information tasks. In this talk, we give an overview of different collision models that have been proposed to simulate the Markovian dynamics of multipartite, structured open quantum systems. We discuss the structure of their master equations, and show that only the recently introduced Multipartite Collision Model is completely general, and on top of that it is proven to be efficiently simulable on a quantum computer. Finally, we show an implementation of this model on near-term quantum devices.

Using Quantum Computer assistance to scale Quantum Discord calculation for nano materials

O. Barış Malcıoğlu

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There is an ongoing worldwide push for "second quantum revolution"1 where quantum effects are treated as a resource. In the context of astrochemistry, one can use Unruh effect to calculate whether the universe is expanding at the same pace everywhere, use Fabbri and Navarro-Salas effect to see if some nano materials are in the vicinity of a black hole (the case of HR 6819) or Unruh–DeWitt detectors to see if something accelerates inside them. Also Moore / Dynamic Casimir effect suggest there might be more clever ways to create new materials. Fermionic correlation measures provide a very interesting tool for this purpose.2,3. This trend aligns well with Such tools require the expertise of both the Quantum Information theory and Quantum Chemistry communities4. This perspective on electronic structure holds the promise to model long range emergent networks, photon- and ion-induced heterogeneities and their spectral consequences5 from first principles; as well as developing novel quantum detector technologies. In alignment with the "second quantum revolution" the approach also allows exploring nano carbon as potent sources of entanglement and quantum correlations, key resources for various quantum technologies. There is also a need for fermionic correlation measures in "first quantum revolution" related topics. This arise from current challenge for quantum chemistry and condensed-matter physics to understand phenomena where critical phenomena and non-equilibrium dynamics go beyond classical mean field approximations6. However, computational tools of quantum information theory do not scale in this regime. For example, in tensor-network representations that most efficiently capture the entanglement in the multipartite system, the cost of classically simulating a general quantum circuit by contracting a tensor network is exponential in the treewidth of the graph induced by the circuit7 which means systems that are more "classical" can have an efficient representation. For restricted classes of systems that are sufficiently unentangled, efficient simulations by tensor networks are possible, but these are not interesting systems in "second quantum revolution" sense. In contrast, systems that are of interest do not have an efficient representation with a classical computer (if it can be represented at all), but, in theory are easy to represent in a quantum computer. However, in the era of intermediate scale noisy quantum computers (NISQ), these higher correlations are the most sensitive to decoherence and thus the output will be hypersensitive to imperfections. The reliability of NISQ quantum simulation is thus most in doubt for exactly those problems we need them for. An approach that combines the advantages of traditional and quantum computing can circumvent this near term issue. This strategy is widely named as "HPC+QPU", where "QPU" stands for "quantum processor unit" and acts as an accelerator in a similar manner to GPU. Preskill laid out a number of examples where this strategy can have advantages such as quantum machine learning8. In this talk, I will go over some of the approaches we are developing in our group with HPC+QPU strategy, in order to scale existing quantum discord measures for describing the electronic structure of nano carbon in space.

Acknowledgments:

The numerical calculations reported in this paper were partially performed at TUBITAK ULAKBIM, High Performance and Grid Computing Center (TRUBA resources), and in VEGA HPC through EuroHPC benchmark access.

(1) Deutsch, I. H. Harnessing the Power of the Second Quantum Revolution. PRX Quantum 2020, 1 (2), 020101. https://doi.org/10.1103/PRXQuantum.1.020101.
(2) Pusuluk, O.; Yesiller, M. H.; Torun, G.; Müstecaplıoğlu, Ö. E.; Yurtsever, E.; Vedral, V. Classical and Quantum Orbital Correlations in the Molecular Electronic States. New J. Phys. 2022, 24 (10), 102001. https://doi.org/10.1088/1367-2630/ac932b.
(3) Brandejs, J.; Veis, L.; Szalay, S.; Barcza, G.; Pittner, J.; Legeza, Ö. Quantum Information-Based Analysis of Electron-Deficient Bonds. The Journal of Chemical Physics 2019, 150 (20), 204117. https://doi.org/10.1063/1.5093497.
(4) Atzori, M.; Sessoli, R. The Second Quantum Revolution: Role and Challenges of Molecular Chemistry. J. Am. Chem. Soc. 2019, 141 (29), 11339–11352. https://doi.org/10.1021/jacs.9b00984.
(5) Ko, W.; Gai, Z.; Puretzky, A. A.; Liang, L.; Berlijn, T.; Hachtel, J. A.; Xiao, K.; Ganesh, P.; Yoon, M.; Li, A.-P. Understanding Heterogeneities in Quantum Materials. Advanced Materials 2023, 35 (27), 2106909. https://doi.org/10.1002/adma.202106909.
(6) Stanley, H. E. Scaling, Universality, and Renormalization: Three Pillars of Modern Critical Phenomena. Rev. Mod. Phys. 1999, 71 (2), S358–S366. https://doi.org/10.1103/RevModPhys.71.S358.
(7) Markov, I. L.; Shi, Y. Simulating Quantum Computation by Contracting Tensor Networks. SIAM J. Comput. 2008, 38 (3), 963–981. https://doi.org/10.1137/050644756.
(8) Biamonte, J.; Wittek, P.; Pancotti, N.; Rebentrost, P.; Wiebe, N.; Lloyd, S. Quantum Machine Learning. Nature 2017, 549 (7671), 195–202. https://doi.org/10.1038/nature23474.

Introduction to self-protected quantum algorithms: quantum simulations

Lianao Wu

Decoherence is a major challenge in quantum computing. To enable execution of quantum algorithms, it is crucial to eliminate decoherence and noise for instance via dynamic decoupling and quantum error correction protocols based on dynamic zero-noise strategy. As potential alternatives we introduced self-protected quantum algorithms over 15 years ago. Quantum algorithms of this kind, based on the living-with-noise strategy, are now used in the Noisy Intermediate-Scale Quantum regime. I will briefly introduce the strategy of self-protectiveness and focus on self-protected quantum simulation in the presence of classical noise.

Advanced Excitation Techniques for Quantum Dots

Yusuf Karlı

Single-photon generation using quantum dots holds immense promise for photonic quantum computing and communication. This talk explores the latest breakthroughs in this field, from excitation to collection techniques. Learn about achieving coherent control of quantum systems through theoretical simulations and experimental results. We'll delve into cutting-edge excitation methods, including the SUPER Scheme, Detour Scheme and Adiabatic Rapid Passage scheme and their impact on the field.

Single-pair measurement of the Bell parameter: testing novel nonlocality bounds while certifying entanglement without destroying it

Fabrizio Piacentini

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In 1965, J. S. Bell [1] turned a philosophical debate into a physical experiment capable of extracting the true nature of correlations within physical systems, opening several research fields spanning from quantum mechanics foundations to quantum technologies [2]. Over the past decades, the scientific community has thoroughly investigated Bell inequalities, eventually achieving loophole-free tests [3-5]. However, some issues persist: e.g., with projective measurements the wavefunction collapse and Heisenberg uncertainty principle forbid performing, on the same quantum system, all the measurements needed for evaluating the entire Bell parameter. Conversely, here we present a method for estimating the entire Bell parameter from each entangled pair while preserving entanglement [6], ensuring its further availability. Such method relies on weak measurements [7], where a tiny coupling between the observed system and the measurement device allows estimating the observables of interest while preventing the state from collapsing: one can therefore measure multiple observables on the same quantum state, extracting all the correlations needed to evaluate the full Bell parameter from each pair (although with a large uncertainty, typical of weak measurements).Our experiment provides new insights into understanding the foundations of quantum mechanics, like the concept of counterfactual definiteness [8]. Moreover, after the entanglement certification, such entanglement remains almost unaltered and therefore exploitable for other quantum information protocols or quantum foundations investigations, like testing novel bounds intertwining local and nonlocal correlations.

[1] J. S. Bell, Physics 1, 195 (1965).
[2] I. Georgescu, Nat. Rev. Phys. 3, 674 (2021).
[3] B. Hensen et al., Nature 526, 682 (2015).
[4] M. Giusna et al., PRL 115, 250401 (2015).
[5] L. K. Shalm et al., PRL 115, 250402 (2015).
[6] S. Virzì et al., arXiv:2303.04787 (2023)
[7] Y. Aharonov, D. Z. Albert & L. Vaidman, PRL 60, 1351 (1988).
[8] Y. Aharonov, A. Botero, S. Popescu, B. Reznik & J. Tollaksen, PLA 301, 130 (2002).

Medical Image Generation Using Quantum Generative Adversarial Networks

Kübra Yeter Aydeniz

Quantum machine learning and generative models for vision have come to the fore recently. However, existing quantum generative adversarial network (QGAN) approaches fail to generate high-quality images due to the limited number of qubits and relatively high level of noise in the current generation of quantum devices. In this talk, I will cover our recent work that aims to address this challenge by proposing a quantum image generative adversarial network (QIGAN) for high-quality image generation. Our variational quantum circuit-based generator of QIGAN addresses scalability issues and generates more diverse set of samples with a significant training efficiency compared to traditional GAN models.

Enhancing Digital Metrology by Employing New Generation Josephson Voltage Standards as Reference

Tezgül COŞKUN ÖZTÜRK

Up to near future, Conventional Josephson Voltage Standard could generate only DC voltages and traceability of AC voltage metrology was based on AC to DC transfer via thermal techniques employing artifacts with small AC-DC difference. The developments in digital to analog converters (DAC) and analog to digital converters (ADC) in speed and resolution made them the choice in instrumentation, and that created the need of new calibration roads that classical AC voltage metrology cannot satisfy the requirements. In this presentation firstly examples of calibration of ADCs using Programable Josephson Voltage Standard and how their calibration is enhanced with the new reference will be introduced. Using the Programmable Josephson Voltage standard a Quantum Voltmeter is established and an Ultra stable DAC is calibrated, measurement results including the comparison between the conventional methods will be presented. Finally, a sampling system is tested using Josephson Arbitrary Waveform Synthesizer and the achievements of this calibration in terms of uncertainty compared to the AC voltage metrology based on thermal techniques will be presented.

Quantum Resources: Pinnacle of Quantum Superposition

Gökhan Torun

Quantum technologies depend on fundamental principles of quantum theory, such as coherence and entanglement. These principles form the basis for their superiority in communication, computation, and information processing across a wide range of applications. These elusive quantum phenomena are comprehensively explained within the framework of quantum resource theories (QRTs). In this talk, I begin with a concise introduction to QRTs, highlighting the hierarchy of quantum states as a key branch that elucidates efficiency in task performance. The talk then explores the challenge of realizing maximal superposition states, also known as golden states, within the resource theory of superposition. By emphasizing the nuanced difference between coherence and superposition in their resource-theoretic formulations, I present a proof for the existence of states with maximal superposition. The presentation concludes by suggesting that Löwdin symmetric orthogonalization can serve as a valuable tool for characterizing pure superposition states, accentuating the profound link between coherence and superposition within the framework of quantum resource theory.

Unifying Stochastic Processes and Quantum Operations

Bilal Cantürk

The conceptual and theoretical differences between classical theories and quantum theory show its effect also in other branches of physics such as stochastic processes and quantum processes [1]. For instance, for finite-dimensional spaces, while the main elements of stochastic processes are probability vectors and stochastic matrices, those of quantum processes are quantum states and quantum operations. These fundamental differences have created a gap between the two fields and thus caused different reformulations of some basic elements of stochastic processes in quantum processes [2, 3]. A possible unification of stochastic processes and quantum operations provides a unique ground on which we can understand better many foundational problems of physics and related fields, such as the difference between the classical and quantum systems, the physics of certain correlations in the classical systems which give rise to certain emergent phenomena. It will also allow us to employ the methods of open quantum systems directly in nonequilibrium statistical physics to study the systems far from equilibrium. Motivated by these issues, we have unified the stochastic and quantum processes for N-level systems by constructing a quantum operational representation of stochastic matrices [4]. This result also provides us with some insight into the quest for the connection between stochastic thermodynamics and quantum thermodynamics [5, 6, 7].
In this talk, in order to clarify the classification of the classical stochastic processes within finite dimensional space, I will first present one of our works, in which we have constructed a P-divisible non-Markovian process [8]. Secondly, I will present how to unify the stochastic processes and quantum operations for N-level systems. Then, I will discuss the classification of the quantum

operations in connection with that of classical stochastic processes. Finally, I will argue about the possible theoretical and philosophical implications of the work in Ref. [4]

References:

[1] A. Rivas, S. F. Huelga and M. B. Plenio, Rep. Prog. Phys, vol. 77, p. 094001, 2014.
[2] H.-P. Breuer, E.-M. Laine, and J. Piilo, Phys. Rev. Lett., vol. 103, p. 210401, 2009.
[3] A. Rivas and S. F. Huelga and M. B. Plenio, Phys. Rev. Lett., vol. 105, no. 5, p. 050403, 2010.
[4] B. Canturk, "Unification of stochastic processes and quantum processes for N-Level systems," (in preparation).
[5] S. Deffner and E. Lutz, Phys. Rev. Lett., vol. 107, no. 14, p. 140404, 2011.
[6] M. Esposito, K. Lindenberg and C. Van den Broeck, New J. Phys., vol. 12, no. 1, p. 013013, 2010.
[7] A. Colla and H.-P. Breuer, Phys. Rev. A, vol. 105, no. 5, p. 052216, 2022.
[8] B. Canturk and H.-P. Breuer, On positively divisible non-Markovian processes, arXiv:2401.12715, 2024.

Fast charging of Dicke Quantum Batteries

Dario Ferraro

Quantum information theorems state that it is possible to exploit quantum resources such as coherence and entanglement to enhance the charging power of quantum batteries, miniaturized devices able to fastly store energy outperforming their classical counterparts. In this direction, we investigate a model of a quantum battery that can be engineered in solid-state and molecular platforms for quantum electrodynamics. It consists of N two-level systems coupled to a single photonic mode in a cavity. We contrast this collective model ("Dicke quantum battery"), to the one in which each two-level system is coupled to its own separate cavity mode ("Rabi quantum battery"). We demonstrate the emergence of a quantum advantage in the charging power of collective quantum batteries [1,2,3].The first experimental evidence of this phenomenology has been reported very recently in a system where fluorescent organic molecules play the role of two-level systems embedded in a microcavity [4].

[1] D. Ferraro, M. Campisi, G. M. Andolina, V. Pellegrini, M. Polini, Phys. Rev. Lett. 120, 117702 (2018).
[2] A. Crescente, M. Carrega, M. Sassetti, D. Ferraro, Phys. Rev. B 102, 245407 (2020).
[3] G. Gemme, G. M. Andolina, F. M. D. Pellegrino, M. Sassetti, D. Ferraro, Batteries 9, 197 (2023).
[4] J. Q. Quach et al., Science Advances 8, eabk3160 (2022).

Development of an Sr Optical Lattice Clock at TUBITAK UME

Mehmet Çelik

The stability of optical atomic clocks has long exceeded that of microwave atomic clocks by a factor of ~100. The definition of the SI second is expected to change in 2030, making optical atomic clocks the primary reference systems. For the aforementioned reasons, we are currently developing an Sr optical lattice clock in our laboratory. The system consists of a cold atomic Sr beam source, a UHV vacuum science chamber expected to reach ~10-12 mbar, an ultra-stable cavity with a fractional frequency instability of ~7x10-16 at 1 s, 7 lasers for cooling, trapping and interrogating the atoms, and a spectral purity transfer system based on an optical frequency comb that transfers the short-term stability of the ultra-stable cavity to the lasers. We expect to achieve clock instability better than 10-17 in the long-term with this optical clock setup. This system is expected to become the backbone of the time-frequency infrastructure in Türkiye.

Wavelet-based magnetometry enhancement of NV centers in diamonds

Ekrem Taha Güldeste

Nitrogen-vacancy (NV) centers in diamonds constitute a solid-state nanosensing paradigm. For high-precision magnetometry of DC or AC fields, the Ramsey or Multipulse sensing sequences are the prevalent choices where the sensing signal is extracted from time-resolved spin-state-dependent photoluminescence (PL) data. The sensitivity of the NV magnetometer is ultimately limited by the photon shot noise, which cannot be sufficiently removed by averaging or frequency filtering. We propose a wavelet-based denoising scheme specifically tailored to suppress shot noise. It simply operates as a post-processing applied on a collected PL time series. Our implementation is template margin thresholding (TMT) which we computationally benchmark, and demonstrate its signal-to-noise-ratio improvement up to an order of magnitude for the case of limited-time-budget DC-field measurements [1]. In this talk, I will focus on the implementation of TMT-enhanced DC magnetometry and discuss the extension of wavelet-based techniques to the sensing of AC fields.

[1] E.T. Güldeste, C. Bulutay, Wavelet-based Ramsey magnetometry enhancement of a single NV center in diamond, (2023), arXiv:2310.18959 [quant-ph].

Quantum Computing for Life Sciences

Özlem Salehi Köken

In this talk, I will talk about applications of quantum computing for life sciences and how Algorithmiq leverages quantum computing to target problems in this domain. The talk will start by introducing the field of quantum chemistry and how Algorithmiq approaches such problems. I will briefly discuss the aurora software platform for chemistry simulations and tensor network error mitigation. Finally, I will talk about the collaborations between Algorithmiq, IBM and Cleveland Clinic, to explore new photon drug interactions in cancer prevention and treatment.

2D Quantum Materials for Single Photon Detection

Mehmet Cengiz Onbaşlı

Single photon detection is a unique kind of sensing that investigates the interaction of quasiparticles such as magnons, excitons, Cooper pairs, polaritons with photons in the quantum limit. All interactions are necessarily quantum due the discrete wave-particle duality of single photons. Thus, either a phase transition (superconducting to resistive, metal-insulator transition, transition edge, avalanche) or a two-level system (TLS) excitation needs to be used to achieve single photon detection. As a result, the preparation of the functional quantum materials that undergo the phase transitions or TLS. In this study, we propose and demonstrate single photon detectors that achieve efficient photon detection using topological 2D magnetic materials. These materials break the time-reversal and space inversion symmetry and thus merge the merits of superconducting-to-metal transition on the surface edge states while exhibiting unidirectional magneto-transport properties. Using computational models for photon absorption as well as experimental growth, e-beam lithography (device fabrication) and characterization results, we discuss single photon detection on surface edge states. These results might suggest new directions for photodetection using 2D quantum materials including transition metal dichalcogenides and magnetic topological insulators that undergo superconducting-to-metallic phase transition for the surface edge states.

Mobile Operators in the Quantum Age: The Next Big Step in Mobile Technology

Buse Bilgin

The rise of quantum technologies presents unique opportunities and challenges in the mobile communications sector. Quantum computing, cryptography, and sensor technologies could fundamentally alter the capacity, security, and efficiency of mobile networks, while the integration of these innovations faces significant barriers such as cost, technical complexity, and compatibility with existing systems. The impact of quantum technologies on mobile operators, with both its advantages and disadvantages, could reshape the competitive landscape in the industry and significantly enhance the end-user experience. This talk aims to provide participants with an in-depth look at the impact of quantum technologies on mobile operators, illuminating the opportunities and challenges that lie ahead in this revolution.

Neuromorphic computing and Superconducting Single Photon Nanowire Detector (SNSPD) applications

Orkun Hasekioğlu

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Abstract—Computing with light using integrated optics has seen huge progress over the last 3-4 years in multiple fields such as neuromorphic computing, quantum computing and on-chip data storage. This has created a vast ecosystem that relies on high-speed reconfigurations of nanophotonic circuits (such as their use as synapses or routing applications) and ultrafast yet high-resolution, low-power photodetection. Currently, it is impossible to combine all these functionalities into an integrated platform that fits onto a single chip. In RESPITE, by utilizing superconducting Joule switches as neurons, multi-level phase change memory elements as synaptic weights, and superconducting single-photon detector arrays as retina we will demonstrate a novel platform which combines vision and cognition on a single chip. This new platform will allow in-sensor neuromorphic computing with unprecedented performance levels The platform will have attoJoule switching power consumption, sub-nanosecond latency, and compactness.

Keywords — PCM, phase change memory, neuromorphic computing, superconducting nanowire single photon detectors (SNSPD)

Posterler / Posters

Advancements in quantum arithmetic: Qudit-based circuits with QFT Subroutine

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In this talk, we present our research on the quantum circuit that performs arithmetic addition/subtraction operations via the quantum Fourier transform (QFT) subroutine algorithm. In particular, we focus on the n-level quantum source called a qudit. In single quantum channels based on qudit, multi-bit numbers can be represented. This allows us to design the QFT-based addition circuit, where each input quantum channel holds a multi-bit unsigned number. In this way, we build the quantum adder that performs the addition operation on two quantum channels as inputs on qubit (n=2) and qukuart (n=4) systems. We also test the idea for the qubit-based quantum computer simulator provided by IBM.

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Voltage-tunable Entanglement Device for continous-variable cluster states via Fano Resonances

Deniz Mol

By preparing qumodes or cluster states before computing, continous variable quantum computers provide reserve for a good amount of computing power. The cluster states can be created via beamsplitters that combine initially-squeezed photons. Here I present that for the first time the initial squeezing (and hence entanglement) can be controllled continously with the apllied voltage. This is done by using plasmonic nanostructures that are coupled to a quantum dot. Coupling of short life time-plasmons to longer life time molecules (QD) causes Fano resonance. By applying voltage through nano-wires to the structure we can control the squeezing level created by the plasmons (Figure-1). The squeezing is created due to plasmonic particles that carry third order nonlinearity. This nonlinearity causes the creation of four-wave mixing process where the output photons are now squeezed. Moreover by using this process to create a frequency comb it enables programmable generation of multi-frequency cluster states.

Josephson Arbitrary Waveform Synthesizer System at TÜBİTAK UME

Tezgül COŞKUN ÖZTÜRK

Josephson Arbitrary Waveform Synthesizer (JAWS) is a quantum voltage standard that can generate arbitrary waveforms, and is a candidate to be a reference for waveform metrology starting from mHz to beyond GHz ranges, and its superconducting integrated circuit (SIC) is still under development. Conventional JAWS system established in TUBİTAK UME firstly run in liquid Helium and metrological measurements obtained with the system will be presented. In order to lower the operation costs the system is moved to top loading crycooler, and studies on electro-optical drive are performed accordingly to the research in the world. New researches to use the system under European Partnership on Metrology Program are planned and will be introduced.

Steady state entanglement of distant nitrogen-vacancy centers in a coherent thermal magnon bath

Kamran Ullah

We investigate steady state entanglement (SSE) between two nitrogen-vacancy (NV) center defects in a diamond host on an ultrathin yttrium iron garnet (YIG) strip. We determine the dephasing and dissipative interactions of the qubits with the quanta of spin waves (magnon bath) in the YIG depending on the qubit positions on the strip. We show that the magnon's dephasing effect can be eliminated, and we can transform the bath into a multimode displaced thermal state using external magnetic fields. Entanglement dynamics of the qubits in such a displaced thermal bath have been analyzed by deriving and solving the master equation. An additional electric field is considered to engineer the magnon dispersion relation at the band edge to control the Markovian character of the open system dynamics. We determine the optimum geometrical parameters of the system of distant qubits and the YIG strip to get SSE. Furthermore, parameter regimes for which the shared displaced magnon bath can sustain significant SSE against the local dephasing and decoherence of NV centers to their nuclear spin environments have been determined. Along with SSE, we investigate the steady state coherence (SSC) and explain the physical mechanism of how delayed SSE appears following a rapid generation and sudden death of entanglement using the interplay of decoherence-free subspace states, system geometry, displacement of the thermal bath, and enhancement of the qubit dissipation near the magnon band edge. A nonmonotonic relation between bath coherence and SSE is found, and critical coherence for maximum SSE is determined. Our results illuminate the efficient use of system geometry, band edge in bath spectrum, and reservoir coherence to engineer system-reservoir interactions for robust SSE and SSC.

Robustness of distance-based quantum resources outside a radiating Schwarzschild black hole

Samira Elghaayda

We examine the distribution of distance-based quantum resources in the proximity of a Schwarzschild black hole within a curved background. For an observer in free fall and their stationary counterpart sharing the bipartite Gisin state, the quantum resources are degraded at an infinite Hawking temperature. The extent of this degradation that occurs as the black hole evaporates is contingent upon the fermionic frequency mode, Gisin state parameters, and the distance between the observer and the event horizon. In the case of two accelerating detectors in Minkowski spacetime interaction with quantum fluctuating scalar fields, we find that quantum coherence and discord exhibit sudden disappearance for certain initial states and sudden reappearance for others except entanglement, regardless of the Unruh temperature. We demonstrate that, in contrast to coherence and discord, we are unable to regenerate entanglement for a given initial state. In certain circumstances, the presence of event horizons does not significantly reduce the available resources, as it turns out that all interesting phenomena occur within event horizons. Since the world is basically non-inertial, it is necessary to understand the distribution of quantum resources within a relativistic framework.

Preparation of thermal coherent state and its role in quantum thermometry

Asghar Ullah

The unavoidable interaction between thermal environments and quantum systems typically leads to the degradation of the quantum coherence, which can be fought against by reservoir engineering. We propose that a thermal coherent state can be realized using a thermally driven two-level system longitudinally coupled to a resonator. Using the master equation approach to describe the open system dynamics, we obtain the steady-state solution of the master equation for the two-level system and resonator. We find that the state of the resonator is a thermal coherent state, while the two-level system remains thermal. This observation is verified by evaluating the second-order correlation coefficient and photon number statistics of the resonator. Moreover, we reveal the potential benefits of employing the thermal coherent state of the resonator in quantum thermometry. In this context, the resonator functions as a probe to measure the unknown temperature of a bath mediated by a two-level system, strategically bridging the connection between the two. Our findings elucidate that using an ancilla-assisted probe may enhance precision and broaden the applicable temperature range.

Quantum Estimation of the Stokes Vector Rotation for a General Polarimetric Transformation

Ali Pedram

Classical polarimetry is a well established discipline with many applications in different branches of science. Ever-growing interest in utilizing quantum resources to make highly sensitive measurements, prompted the researchers to describe polarized light in a quantum mechanical framework and build a quantum theory of polarimetry. In this work, inspired by polarimetric studies in biological tissues, we study the ultimate limit of rotation angle estimation with a known rotation axis in a quantum polarimetric process, which consists of three quantum channels. The rotation angle to be estimated is induced by the retarder channel on the Stokes vector of the probe state. However, the diattenuator and depolarizer channels act on the probe state, which effectively can be thought of as a noise process. Finally the quantum Fisher information (QFI) is calculated and the effect of these noise channels and their ordering is studied on the estimation error of the rotation angle.

Establishing a Cryocooled Programmable Josephson Voltage Standard in TÜBİTAK UME

Mehedin Arifoviç

The recent development of Josephson arrays, which have been used as DC voltage standards for decades, has led to their increasing use in AC voltage measurement. In order to use their potential in testing the latest digital technology, we established a new voltage standard at the TÜBİTAK UME based on a programmable 10V Josephson array installed in a cryogenic cooler. Work included array integration into the cryocooler, wiring, control software development, and system validation. In our presentation, we will give details about the construction, functionality testing, and the use of the new standard in measurements.

Quantum Spin Glasses in Quantum Otto Engines

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We present a study of a four-stroke Quantum Otto Engine [1] with a quantum spin-glass represented by the Edwards-Anderson (EA) and Sherrington-Kirkpatrick (SK) spin-glass models [2, 3] as the working medium. Quantum spin glasses have been a significant area of interest in quantum many-body physics due to their exotic properties, which give rise to many interesting applications such
as neural networks, quantum computation and quantum annealing, and combinatorial optimization problems[4].
The Quantum Otto Engine we study consists of two adiabatic strokes of magnetic field quench and two isochoric thermalization processes. We investigate the two quantities thermodynamic performance and work output defined in [5] according to initial magnetic field and system size. For both models, we observe that at low temperatures (Th < Tg , where Tg is the spin glass transition temperature), the quantum spin glass displays super-linear scaling and enhancement in thermodynamic performance indicated by a peak around the critical points [1, 5]. After the transition temperature, Tg , the peak begins to dissolve. At higher temperatures we observe slow decay
consistent with spin-glass slow relaxation behavior.

References:
[1] G. Piccitto, M. Campisi, and D. Rossini, New Journal of Physics 24, 103023 (2022).
[2] S. F. Edwards and P. W. Anderson, Journal of Physics F: Metal Physics 5, 965 (1975).
[3] D. Sherrington and S. Kirkpatrick, Phys. Rev. Lett. 35, 1792 (1975).
[4] H. Nishimori, Statistical physics of spin glasses and information processing: an introduction (Oxford Univer-sityPress,2001).
[5] M. Campisi and R. Fazio, Nature Communications 7, 11895 (2016).

Some Applications of Quantum Phase Estimation for Qubits and Qudits

Ayda KALTEHEI

Quantum computing has become a promising research area and it is based on quantum mechanical principles. A d-dimensional (d>2) unit of information in quantum computing is called a qudit. The quantum parallelism is a key advantage for quantum algorithm used in quantum computing. Quantum Fourier Transform (QFT) is used in order to obtain superposition of quantum states in order to have quantum parallelism. QFT is basic block of some quantum algorithms such as Quantum Phase Estimation (QPE). In this study, first, simulations of QPE algorithm is performed for some qubit and qudit states. Then, the comparison of QPE for qubits and ququarts are made in order to show that ququarts are more advantageous for this algorithm.

Nonclassical properties of the q-deformed pointer states in weak measurement

Seyyedeh Elham Mousavigharalari

Nonclassical q-deformed coherent states introduced via Quesne in [1], satisfy the unitary resolution relation with a non-deformed integral. Using these states as the pointer states in the weak measurement regime we aim to investigate the important parameters in quantum optics including the probability of finding n photons in such q-coherent state pointers, sub-Poissonian statistics, antibunching effect of these types of q-coherent state probes, and the signal-to-quantum noise ratio (SNR). We exploit these states to show that the nonclassicality of the system is increased by exploiting these types of q-deformed coherent states under the weak measurement regime. It is observed that the degree of nonclassicality depends on the deformation parameter (q) and the interaction factor of the weak measurement (g). In other words, it is obvious that the distribution function becomes more sub-Poissonian and the antibunching effect becomes stronger under the q-post-selected weak measurement. Moreover, the ratio of the signal detected by the system to the noise will be amplified.

Mass-Independent Scheme to Test the Quantumness of a Massive Object

Debarshi Das

The search for empirical schemes to evidence the nonclassicality of large masses is a central quest of current research. However, practical schemes to witness the irreducible quantumness of an arbitrarily large mass are still lacking. To this end, we incorporate crucial modifications to the standard tools for probing the quantum violation of the pivotal classical notion of macrorealism (MR): while usual tests use the same measurement arrangement at successive times, here we use two different measurement arrangements. This yields a striking result: a mass-independent violation of MR is possible for harmonic oscillator systems. In fact, our adaptation enables probing quantum violations for literally any mass, momentum, and frequency. Moreover, coarse-grained position measurements at an accuracy much worse than the standard quantum limit, as well as knowing the relevant parameters only to this precision, without requiring them to be tuned, suffice for our proposal. These should drastically simplify the experimental effort in testing the nonclassicality of massive objects ranging from atomic ions to macroscopic mirrors in LIGO.

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Protection of Quantum Coherence by Optimizing Network Geometry

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We investigate how the geometry of buffer networks impacts the protection of quantum coherence in spin clusters that interact with thermal environments. We explore all buffer networks that can be embedded in a plane and find that the connectivity of the buffer network is crucial in determining the protection time of quantum coherence in a single central spin. Our results indicate that the maximal planar graph provides the longest protection time for a fixed number of buffer spins. However, increasing the number of buffer spins does not always lead to longer protection times. With the help of a quantum master equation, our simulations show that a tetrahedral geometry of a four-spin buffer network offers the most optimal protection against environmental effects. These findings could help us to better understand biochemical processes since we frequently observe tetrahedral geometry in natural molecules.

Energetics of autonomous quantum systems: A Schmidt Decomposition Approach

André Hernandes Alves Malavazi

The development of a self-consistent thermodynamic theory of quantum systems is of fundamental importance for modern physics. Still, despite its essential role in quantum science and technology, there is no unifying formalism for characterizing the thermodynamics within general autonomous quantum systems, and many fundamental open questions remain unanswered. Along these lines, most current efforts and approaches restrict the analysis to particular scenarios of approximative descriptions and semi-classical regimes. Here, we propose a novel approach to describe the thermodynamics of arbitrary bipartite autonomous quantum systems based on the well-known Schmidt decomposition. This formalism provides a simple, exact, and symmetrical framework for expressing the energetics between interacting systems, including scenarios beyond the standard description regimes, such as strong coupling. We show that this procedure allows straightforward identification of local effective operators suitable for characterizing the physical local internal energies. We also demonstrate that these quantities naturally satisfy the usual thermodynamic notion of energy additivity.

A quantum Otto engine with shortcuts to thermalization and adiabaticity

Serhat Kadıoğlu

We investigate the energetic advantage of accelerating a quantum harmonic oscillator Otto engine by use of shortcuts to adiabaticity (for the expansion and compression strokes) and to equilibrium (for the hot isochore), by means of counter-diabatic (CD) driving. By comparing various protocols with and without CD driving, we find that, applying both type of shortcuts leads to enhanced power and efficiency even after the driving costs are taken into account. The hybrid protocol not only retains its advantage in the limit cycle, but also recovers engine functionality (i.e. a positive power output) in parameter regimes where an uncontrolled, finite-time Otto cycle fails. We show that controlling three strokes of the cycle leads to an overall improvement of the performance metrics compared with controlling only the two adiabatic strokes. Moreover, we numerically calculate the limit cycle behavior of the engine and show that the engines with accelerated isochoric and adiabatic strokes display a superior power output in this mode of operation.

Hybrid Realization of Quantum Mean Filters with Different Sized on E-NEQR Quantum Images by QFT Based Operations

İbrahim Emre Kıvanççı

This paper presents a novel quantum-based method for noise reduction in quantum images using a combination of QFT-based mathematical functions and optimized classical partitioning techniques The method uses an image pixel values are mapped to real kets in Hilbert space using block structured addressing systems. The resulting state is then reformulated into a matrix-product-state representation, where quantum entanglement reveals classical correlations between different coarse-grained textures by using the Enanched novel enhanced quantum representation of digital images (E-NEQR) model to facilitate inversion classical image data into a grayscale quantum model. The study focuses on determining the optimal filtering actuator size to strike a balance between noise reduction and potential image blurring. This research contributes to theoretical insights and practical techniques for effectively reducing noise in quantum images, while preserving image quality.

Electrically-programmable Integrated Four-Wave Mixing Device

Gunça Niyazmetova

Plasmonic Nanostructures can possess nonclassicalities such as squeezed and entangled states. Squeezed states are an indespensable resources for quantum information processing and photonic quantum computers utilizing entangled photons. Here we Show, for the first time, that one can control the squeezed states via an applied voltage.
In photonic quantum computers, we can use Four-Wave mixing (FWM) to create a “frequency comb” which can control the quantum logic gates. Squeezed states that are created via FWM can be used to control cluster states that are working in different frequencies.

In our system we used a gold nanoparticle coupled to a two level quantum dot, where we have controlled the FWM signal. Interaction of gold nanoantenna and quantum dot resulted in 230 times enhancement in the FWM signal.

We have found that along with signal enhancement and suppresion of FWM signal, we can also control the entanglement degree between photons via applied voltages.

Dynamics in Yang-Baxter Systems: Coherence, Quantum Fisher Information and Quantum Thermometry

Durgun Duran

Since Yang-Baxter (YB) systems are easy to prepare and manipulate in quantum information experiments they are of increasing interest in many fields such as the estimation of physical parameters, dynamics of quantum coherence, quantum thermodynamics, and so on. We shall study the dynamics of quantum coherence and quantum Fisher information for the estimation of parameters, especially in the context of quantum thermometry using two-qubit states under the action of the Yang-Baxter matrices and Hamiltonians constructed by the YB equation. Although these quantities are monotonically decreasing under the action of a quantum channel in a noisy environment, it can be shown that mitigation of these decreases providing relative enhancements in quantum Fisher information and quantum coherence is possible through Yang-Baxter matrices that model unitary quantum channels or noises.