3d SWEDISH—UKRAINIAN SEMINAR in THEORETICAL PHYSICS

May 28, 2024

Mixed on-line/off-line regime*

Program**

10.00–10.05 – Opening

10.05–10.45 – **Fabio Costa** (Stockholm University, Sweden) **“Quantum causal structures and quantum non-Markovianity”**

10.45–11.15 – **Andriy Semenov** (Bogolyubov Institute For Theoretical Physics, NAS of Ukraine, Kyiv, Ukraine) **“Revealing quantum properties with realistic measurements”**

11.15–11.45 – **Khrystyna Gnatenko** (Ivan Franko National University of Lviv) **“Quantum algorithms for studies of the properties of spin systems and spin-1 tunneling”**

11.45–12.00 – Coffee break

12.00–12.40 – **Jan-Åke Larsson** (Linköping University, Sweden) **“Quantum computation and the additional degrees of freedom in quantum bits”**

12.40–13.10 – **Sergey Shevchenko** (*B. Verkin Institute for Low Temperature Physics and Engineering, Kharkiv, Ukraine*) **“Strongly driven qubit-resonator system: Landau-Zener-Stuckelberg-Majorana interferometry”**

***zoom ID for the meeting**:

https://kth-se.zoom.us/j/68315431943

****EE Time, CE Time is one hour earlier**

Quantum causal structures and quantum non-Markovianity

Fabio Costa

Stockholm University, Sweden

The characterisation of non-Markovian open quantum systems has been a long-standing subject of debate: usual descriptions in terms of a time-evolving states fail in the presence of system-environment correlations, and the general treatment of classical stochastic processes does not generalise directly, because quantum measurements necessarily disturb the system. I will present an approach based on quantum causal structures, where the open system is characterised as a multi-time process, providing all and only the information obtainable by probing the system.

Revealing quantum properties with realistic measurements

Andriy Semenov

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Kyiv, Ukraine

Optical nonclassicality and Bell nonlocality are archetypal examples of quantum resources applied in a variety of quantum technologies and fundamental studies. However, imperfections of realistic measurement devices, especially those used in quantum optics, can significantly reduce our chances of detecting quantum properties of light. The purpose of this talk is twofold. First, I will present our recent results on the theory of realistic photodetection [1-3]. Second, I will discuss inequalities that may reveal nonclassical and nonlocal properties for quantum states of light analyzed with such imperfect and informationally incomplete measurements [4,5].

[1] V. A. Uzunova and A. A. Semenov, Photocounting statistics of superconducting nanowire single-photon detectors, Phys. Rev. A **105**, 063716 (2022).

[2] A. A. Semenov, J. Samelin, Ch. Boldt, M. Schünemann, C. Reiher, W. Vogel, and B. Hage, Photocounting measurements with dead time and afterpulses in the continuous-wave regime, Phys. Rev. A **109**, 013701 (2024).

[3] E. V. Stolyarov, O. V. Kliushnichenko, V. S. Kovtoniuk, and A. A. Semenov, Photon-number resolution with microwave Josephson photomultipliers, Phys. Rev. A **108**, 063710 (2023).

[4] V. S. Kovtoniuk, I. S. Yeremenko, S. Ryl, W. Vogel, and A. A. Semenov, Nonclassical correlations of radiation in relation to Bell nonlocality, Phys. Rev. A **105**, 063722 (2022).

[5] V. S. Kovtoniuk, E. V. Stolyarov, O. V. Kliushnichenko, A. A. Semenov, Tight inequalities for nonclassicality of measurement statistics, Phys. Rev A **109** (2024) – to appear. ArXiv: https://doi.org/10.48550/arXiv.2310.14263.

Quantum algorithms for studies of the properties of spin systems and spin-1 tunneling

Khrystyna Gnatenko

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We developed algorithms for quantifying the energy levels of spin systems based on studies of the evolution of a probe spin on a quantum device [1]. In cases when an operator anticommuting with the Hamiltonian exists, we proposed an algorithm based on studies of the evolution of the mean value of the physical quantity corresponding to the operator [2]. These algorithms were implemented on quantum computers to detect the energy levels of various spin systems, including a spin in a magnetic field, the Ising model on a squared lattice, and a spin chain [1,2]. We concluded that the algorithms are noise-resistant and open possibilities for achieving quantum supremacy with the development of multi-qubit quantum devices.

A quantum algorithm for observing spin-1 tunneling [3] was also developed [4]. The spin-1 system was modeled with two spin-1/2 particles, and the splitting of energy levels was detected based on studies of the evolution of a probe spin on a quantum device [4].

Additionally, we studied the quantum states of spin systems with Ising model, which can be considered as quantum graph states corresponding to unweighted and undirected graphs. Quantum protocols for detecting the geometric properties [5] of these states were developed and realized on quantum processors [6]. As a result, we identified the velocity of quantum evolution, the curvature, and the torsion of the states. We also demonstrated that these characteristics are related to the graph properties, including the number of edges, triangles, and squares in a graph. Therefore, classical graph characteristics can be detected through quantum programming. Furthermore, we proposed quantum algorithms for analyzing the properties of weighted and directed graphs on a quantum computer, based on studies of the properties of quantum graph states of spin systems.

References

[1] Kh. P. Gnatenko, H. P. Laba, V. M. Tkachuk, Detection of energy levels of a spin system on a quantum computer by probe spin evolution. Eur. Phys. J. Plus 137 (2022) 522.

[2] Kh. P. Gnatenko, H. P. Laba, V. M. Tkachuk, Energy levels estimation on a quantum computer by evolution of a physical quantity. Phys. Lett. A. 424 (2022) 127843.

[3] J. Fernandez-Rossier, Theory of single-spin inelastic tunneling spectroscopy Phys. Rev. Lett. 102 (2009) 256802.

[4] Kh. P. Gnatenko, V. M. Tkachuk, Observation of spin-1 tunneling on a quantum computer. Eur. Phys. J. Plus. 138 (2023) 346.

[5] H. P. Laba, V. M. Tkachuk, Geometric characteristics of quantum evolution: curvature and torsion Condens. Matter Phys. 20 (2017) 13003.

[6] Kh. P. Gnatenko, H. P. Laba, V. M. Tkachuk, Geometric properties of evolutionary graph states and their detection on a quantum computer. Phys. Lett. A. 452 (2022) 128434.

Quantum computation and the additional degrees of freedom in quantum bits

Jan-Åke Larsson

Linköping University, Linköping, Sweden

The speed-up of Quantum Computers is the current drive of an entire scientific field with several large research programmes both in industry and academia world-wide. Many of these programmes are intended to build hardware for quantum computers. A related important goal is to understand the reason for quantum computational speed-up; to understand what resources are provided by the quantum system used in quantum computation. Some candidates for such resources include superposition and interference, entanglement, nonlocality, contextuality, and the continuity of state-space. The standard approach to these issues is to restrict quantum mechanics and characterize the resources needed to restore the advantage. Our approach is dual to that, instead extending a classical information processing systems with additional properties in the form of additional degrees of freedom, normally only present in quantum-mechanical systems. In this talk, we will have a look at these additional degrees of freedom including the effect of Pauli-group contextuality, and how quantum computers make use of them to achieve the quantum speedup.

Strongly driven qubit-resonator system: Landau-Zener-Stuckelberg-Majorana interferometry

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Our recent interest was to study the strongly driven dissipative qubit-resonator system in the situation when they are strongly coupled and the resonator is the quantum one. For this we transform the Hamiltonians, introduce dressed states, discuss two-tone spectroscopy, solve the Lindblad equation, plot interferograms. I am going to tell about these, while not to make the talk boring, I'll tell also about the Landau-Zener-Stuckelberg-Majorana (LZSM) physics.

In spite of its almost century-old history, LZSM transitions remain a subject of interest. Why does it remain an evergreen topic? Why is it called by many "Landau-Zener transition", while Majorana was the first to describe it and Stuckelberg wrote the same year a huge detailed paper resulting in the same formula? I will tell about these and other related issues at the seminar; and also you can read about this in our papers [1,2] as well as enjoy reading in other very recent illustrative papers by others [3,4] and with our participation [5,6].

References:

[1] O.V. Ivakhnenko, S.N. Shevchenko, and F. Nori, Nonadiabatic Landau-Zener-Stuckelberg-Majorana transitions, dynamics, and interference, Phys. Rep. **995**, 1-89 (2023).

[2] P.O. Kofman et al., Majorana's approach to nonadiabatic transitions validates the adiabatic-impulse approximation, Sci. Rep. **13**, 553 (2023).

[3] E. P. Glasbrenner, Y. Gerdes, S. Varró, and Wolfgang P. Schleich, A different perspective on the Landau-Zener dynamics, arXiv:2404.08466.

[4] L. Peyruchat et al., Landau-Zener without a Qubit: Unveiling Multiphoton Interference, Synthetic Floquet Dimensions, and Dissipative Quantum Chaos, arXiv:2404.10051.

[5] J. He et al., Quantifying quantum coherence of multiple-charge states in tunable Josephson junctions, npj Quantum Inf. **10**, 1 (2024).

[6] A.I. Ryzhov et al., Alternative fast quantum logic gates using nonadiabatic Landau-Zener-Stückelberg-Majorana transitions, arXiv:2310.17932.