QI 35: Quantum Information: Concepts and Methods II

Time: Thursday 14:30–16:45 Location: HS IV

QI 35.1 Thu 14:30 HS IV

Teaching Quantum Information in High School — •Mariana Filipova — University of Library Studies and Information Technologies, Sofia, Bulgaria

Quantum science and technology are developing at an ever faster and larger scale, and this necessitates new educational approaches and updates. School education aims, on the one hand, to prepare students for university and the labor market, and on the other hand, to motivate with its applicability and inspiring realizations towards the students' next choices, incl. STEM professions. In order to inspire young people at the most appropriate time to make these choices and strengthen the academy-business connection, it is increasingly necessary that secondary school students also become familiar with the basics of Quantum Information. This study aims to demonstrate the feasibility of teaching quantum science concepts to school-aged students by adapting content and using appropriate and varied methodologies. The aim is to explain the seemingly complex science in an accessible way to middle schoolers and also to inspire young minds for future challenges. The current research highlights the need to update the curriculum and ways of applying recent STEM trends to the work of school-age students to meet the new demands of time and student interests, making quantum science both accessible and exciting for them.

QI 35.2 Thu 14:45 HS IV

Ultradecoherence model of the measurement process — •Hai-Chau Nguyen — University of Siegen

Measurements remain as an interesting topic of research since the formulation of quantum theory. Attempts to model quantum measurements by unitary processes are prone to various foundational issues. Here, it is proposed that measurement devices can be modelled to have an open decoherence dynamics that is faster than any other relevant timescale, which is referred to as the ultradecoherence limit. In this limit, it is shown that the clicking rate of measurement devices can be derived from its underlying parameters, not only for the von Neumann ideal measurement devices but also for photon detectors in equal footing. This study offers a glimpse into the intriguing physics of measurement processes in quantum mechanics, with many aspects open for further investigation.

QI 35.3 Thu 15:00 HS IV

Entangled quantum trajectories in relativistc systems — •Yannick Noel Freitag[1], Julien Pinske[2], and Jan Sperling[1] — [1]Theoretical Quantum Science, Institute for Photonic Quantum Systems (PhoQS), Paderborn University, Warburger Straße 100, 33098 Paderborn, Germany — [2]Niels Bohr Institute, University of Copenhagen, Blegdamsvej 17, 2100 Copenhagen, Denmark

Quantum entanglement is a key resource for quantum technologies, including emerging ground-to-satellite quantum communication. In such a scenario, an important challenge is to consider entanglement between two or more quantum particles in different inertial frames. In this talk, we present a consistent framework that overcomes this challenge. To this end, we establish the notion of factorizable and entangled multi-time trajectories and derive a class of Euler–Lagrange equations under the constraint of a non-entangling behavior. Comparing this restricted evolution to the solutions of the unrestricted equations of motion allows one to investigate the trajectory-based entanglement of general systems. We solve our equations for interacting particles in a Klein–Gordon-type setting, thereby quantifying the dynamic and relativistic impact of entanglement in a self-consistent manner.

QI 35.4 Thu 15:15 HS IV

Exploring Photon-Number-Encoded High-dimensional Entanglement from a Sequentially Excited Quantum Three-Level System — Daniel A. Vajner[1], •Nils D. Kewitz[1], Martin von Helversen[1], Stephen C. Wein[2], Yusuf Karli[2], Florian Kappe[3], Vikas Remesh[3], Saimon F. Covre da Silva[4,5], Armando Rastelli[4], Gregor Weihs[3], Carlos Anton-Solanas[6], and Tobias Heindel[1] — [1]Institute of Solid State Physics, Technische Universität Berlin, Germany — [2]Quandela, Massy, France — [3]Institut für Experimentalphysik, Universität Innsbruck, Austria — [4]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Austria — [5]Universidade Estadual de Campinas, Instituto de Física Gleb Wataghin, Brazil — [6]Departamento de Física de Materiales, Instituto Nicolás Cabrera, Instituto de Física de la Materia Condensada, Universidad Autónoma de Madrid, Spain

Here, we experimentally implement a sequential two-photon resonant excitation process driving a solid-state 3-level system, represented by a semiconductor quantum dot [1]. The resulting light state exhibits entanglement in time and energy, encoded in the photon-number basis. Performing energy- and time-resolved correlation experiments together with detailed theoretical modeling, we are able to partially retrieve the entanglement structure of the generated state and extract an upper bound for the fidelity to the entangled target state of $\mathcal{F} \leq 70\%$ before loss.

[1] Vajner et al., Optica Quantum, DOI:10.1364/OPTICAQ.538134 (2024)

QI 35.5 Thu 15:30 HS IV

Exploring Imaginary Coordinates: Disparity in the Shape of Quantum State Space in Even and Odd Dimensions — Simon Morelli[1], Santiago Llorens[2], and •Jens Siewert[3,4] — [1]Atominstitut, Technische Universität Wien, 1020 Vienna, Austria — [2]Física Teórica: Informació i Fenómens Quántics, Universitat Autónoma de Barcelona, 08193 Bellaterra, Spain — [3]University of the Basque Country UPV/EHU and EHU Quantum Center, 48080 Bilbao, Spain — [4]Ikerbasque, Basque Foundation for Science, 48013 Bilbao, Spain

The state of a finite-dimensional quantum system is described by a density matrix that can be decomposed into a real diagonal, a real off-diagonal and and an imaginary off-diagonal part. The latter plays a peculiar role. While it is intuitively clear that some of the imaginary coordinates cannot have the same extension as their real counterparts the precise relation is not obvious. We give a complete characterization of the constraints in terms of tight inequalities for real and imaginary Bloch-type coordinates. Our description entails a three-dimensional Bloch ball-type model for the state space. We uncover a surprising qualitative difference for the state-space boundaries in even and odd dimensions.

QI 35.6 Thu 15:45 HS IV

Deciding finiteness of Hamiltonian algebras — •David Edward Bruschi — Institute for Quantum Computing Analytics (PGI-12), Forschungszentrum Jülich, Jülich, Germany

Determining exactly the dynamics of a physical system is the paramount goal of any branch of physics. Quantum dynamics are characterized by the non-commutativity of operators, which implies that the dynamics usually cannot be tackled analytically and require ad-hoc solutions or numerical approaches. A priori knowledge on the ability to obtain exact results would be of great advantage for many tasks of modern interest, such as quantum computing, quantum simulation and quantum annealing.

In this work we build on our approach previously introduced to determine the dimensionality of a Hamiltonian Lie algebra by appropriately characterizing its generating terms. In the original exact and fully general approach, we started to develop new tools to determine the final dimension of the algebra itself. We here extend the initial proposal by including a time-independent free Hamiltonian drift term, which improves the original proposal by allowing to tackle all bosonic Hamiltonians.

We are able to provide statements on the ultimate ability to exactly control the dynamics or simulate specific classes of physical systems of coupled quantum harmonic oscillators. This work has important implications not only for theoretical physics, but it also aids our understanding of the structure of the Hilbert space, as well as Lie algebras.

QI 35.7 Thu 16:00 HS IV

A Color Center based Scheme for the Storage and Retrieval of a Quantum Token — •Yannick Strocka, Mohamed Belhassen, Gregor Pieplow, and Tim Schröder — Institut für Physik, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Deutschland

Quantum tokens are of growing interest in the era of secure communication in large scale quantum networks. Compared to classical tokens they are unforgeable because of the no-cloning principle. A quantum token can be a multi-qubit state comprised of single or entangled qubits. Such multi-qubit states can be efficiently produced using single photon sources, such as quantum dots or color centers in diamond. For a practical implementation of a quantum token scheme a token has to be issued and a user has to have the ability to save and redeem the token. In this work we focus on the user, possessing a register of quantum memories based on group-IV color centers in diamond. Such defects are promising due to their long spin coherence times and reduced sensitivity to electric field noise when integrated into nanostructures. In our proposed scheme, saving the token using the color centers' spin requires the use of a spin rotation and spin dependent reflection of the incoming photons. For performing such a rotation quickly we investigate optical spin gates using a Raman scheme. We analyze the impact of imperfections of the photon source, spin rotations and measurement on the resulting fidelity of the quantum token. We also study the overall performance of the spin based quantum memory register for receiving and sending quantum tokens.

QI 35.8 Thu 16:15 HS IV

Entropic witness for quantum memory — •Charlotte Bäcker[1], Konstantin Beyer[2], and Walter Strunz[1] — [1]TUD Dresden University of Technology, 01062, Dresden, Germany — [2]Stevens Institute of Technology, Hoboken, New Jersey, 07030, USA

In quantum physics, non-Markovian processes arise from the interaction between the quantum system and its environment whenever memory effects play a role. The question of whether the memory provided by the environment can be considered classical or requires a quantum description is part of an ongoing debate. We present a witness for quantum memory based on entropy, which can be computed for any dimension of the quantum system of interest. This approach will be illustrated by an application of the witness to qudit dynamics as well as to continuous-variable Gaussian dynamics.

QI 35.9 Thu 16:30 HS IV

Characterising quantum memory via constrained separability problems — •Ties-Albrecht Ohst[1], Shijun Zhang[3], Hai Chau Nguyen[1], Martin Plávala[2], and Marco Túlio Quintino[3] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Siegen 57068, Germany — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, Hannover, Germany — [3]Sorbonne Université, CNRS, LIP6, F-75005 Paris, France

Quantum memories are a crucial precondition in many protocols for processing quantum information. A fundamental problem that illustrates this statement is given by the task of channel discrimination, in which an unknown channel drawn from a known random ensemble should be determined by applying it for a single time. In this talk, we characterise the quality of channel discrimination protocols when the quantum memory, quantified by the auxiliary dimension, is limited. This is achieved by formulating the problem in terms of separable quantum states with additional affine constraints that all of their factors in each separable decomposition obey. We discuss the computation of upper and lower bounds to the solutions of such problems which allow for new insights into the role of memory in channel discrimination. Moreover, the versatility of constrained separability problems in exploring general memory effects, whether classical or quantum, in quantum processes will be showcased.