Q 41: Quantum information: Concepts and methods III

Time: Wednesday 14:00–16:00 Location: E 214

Group Report Q 41.1 Wed 14:00 E 214

Quantum contextuality: state-independent inequalities, dimension witnesses, and challenges for new experiments — •Matthias Kleinmann[1], Jochen Szangolies[1], Costantino Budroni[1], Otfried Gühne[1], Adán Cabello[2], and Jan-Åke Larsson[3] — [1]Universität Siegen, D-57068 Siegen, Germany — [2]Universidad de Sevilla, E-41012 Sevilla, Spain — [3]Linköpings Universitet, SE-58183 Linköping, Sweden

Quantum mechanics cannot be explained by a non-contextual classical theory. This fact was pioneered by Kochen and Specker and is one of the fundamental features of quantum measurements. In a non-contextual classical theory, the outcome of a measurement must be independent of the measurement context, i.e., independent of any other measurements that are performed along with it. But quantum mechanics does not obey this rule, as can be shown by the violation of a non-contextuality inequality. Such inequalities are a natural generalization of Bell inequalities and in particular it is possible to find non-contextuality inequalities that are violated for *any* quantum state, even the completely mixed state. In this talk, recent results will be summarized, in particular the construction of the most fundamental state-independent inequality and the dimension-dependence of the violation of a non-contextuality inequality. Despite quantum contextuality has been demonstrated in several experiments, many questions and challenges remain open and shall also be outlined in this talk.

Q 41.2 Wed 14:30 E 214

Concept for a remote, balanced receiver for quantum key distribution — •Jan Gniesmer, Vitus Händchen, Tobias Eberle, and Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover and Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstr. 38, 30167 Hannover, Germany

Entanglement-based continuous variable quantum key distribution networks rely on the efficient distribution and detection of quadrature entangled states. The distribution can be realized by coupling entangled states of light at 1550nm to optical fibers. This has been previously realized for squeezed states with high efficiency [Mehmet 2010]. In this talk I will present a scheme for distributing entangled states through 1km of fiber and measuring their quadrature amplitudes with balanced homodyne detection. This stand-alone receiver requires a phase lock of its local oscillator and polarization control of the distributed states.

Q 41.3 Wed 14:45 E 214

Simulation of sparse qubit systems — •Robert Zeier — Technische Universität München, Department Chemie, Lichtenbergstr. 4, 85747 Garching

We simulate the effect of unitary transformations on multi-qubit systems. The memory requirements arising from a exponentially growing state space are managed by assuming that the density matrix stays sparse during the simulation. We replace the customary matrix exponentiation with optimized computations in structure-constant Lie algebras. This allows us to better account for efficiency and sparsity while increasing the number of qubits. We present computer experiments with several tens of qubits and explore applications to the simulation of quantum algorithms.

Q 41.4 Wed 15:00 E 214

Robustness of quantum memories based on Majorana zero modes — Leonardo Mazza[1,2], •Matteo Rizzi[1,3], Mikhail Lukin[4], and Ignacio Cirac[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, D-85748 Garching, Germany — [2]Scuola Normale Superiore, piazza dei Cavalieri 7, I-56127, Pisa, Italy — [3]Institut für Physik, Johannes-Gutenberg-Universität Mainz, Staudingerweg 7, D-55128 Mainz, Germany — [4]Physics Department, Harvard University, Cambridge, Massachusetts 02138, USA

We analyze the quantum memory based on a Kitaev chain containing Majorana zero modes in the presence of perturbations. We first derive a closed expression for the fidelity of the best recovery operation acting on the memory after the storage time and aimed at retrieving the initial encoded information. We then apply it to study the robustness of the memory to Hamiltonian (time-dependent) perturbations, as well as to particle losses. In the first case, the memory time grows exponentially with the system size only when the perturbed Hamiltonian is within the topological phase, and even if the perturbation contains frequencies that lie well above the gap. At the same time, the memory is unstable to particle losses.

Q 41.5 Wed 15:15 E 214

Quantum Circuit Implementation of Cyclic Mutually Unbiased Bases — •Ulrich Seyfarth, Niklas Dittmann, and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt, Germany

Complete sets of mutually unbiased bases (MUBs) play an important role in the areas of quantum state tomography and quantum cryptography. Sets which can be generated cyclically may eliminate certain side-channel attacks. To profit from the advantages of these MUBs we propose a method for deriving a quantum circuit that implements the generator of a set into an experimental setup. For some dimensions this circuit is minimal. The presented method is in principle applicable for a larger set of operations and generalizes recently published results [1]. Financial support by CASED is acknowledged.

[1] U. Seyfarth and K. S. Ranade, Phys. Rev. A 84, 042327 (2011)

Q 41.6 Wed 15:30 E 214

Quantum Walks with Nonorthogonal Position States — •Robert Matjeschk[1], Andre Ahlbrecht[1], Martin Enderlein[2], Christopher Cedzich[1], Albert H. Werner[1], Michael Keyl[3], Tobias Schaetz[2], and Reinhard F. Werner[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany — [2]Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, Hermann-Herder-Str. 3, 79104 Freiburg, Germany — [3]ISI Foundation, Via Alassio 11/c, 10126 Torino - Italy

Quantum walks have by now been realized in a large variety of different physical settings. In some of these, particularly with trapped ions, the walk is implemented in phase space, where the corresponding position states are not orthogonal. We develop a general description of such a quantum walk and show how to map it into a standard one with orthogonal states, thereby making available all the tools developed for the latter. This enables a variety of experiments, which can be implemented with smaller step sizes and more steps. Tuning the non-orthogonality allows for an easy preparation of extended states such as momentum eigenstates, which travel at a well-defined speed with low dispersion. We introduce a method to adjust their velocity by momentum shifts, which allows to experimentally probe the dispersion relation, providing a benchmarking tool for the quantum walk, and to investigate intriguing effects such as the analog of Bloch oscillations.

Q 41.7 Wed 15:45 E 214

Quasi phase-locking without a phase reference — •Christian R. Müller[1,2], Petr Marek[3], Radim Filip[3], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Department of Physics, University of Erlangen-Nuremberg, Germany — [3]Department of Optics, Palacký University, Olomouc, Czech Republic

The common approach to lock the phases of two quantum states is to individually couple them to a phase reference, e.g. a bright local oscillator, which can then directly be locked. However, if a bright phase reference cannot be provided the phase information is typically insufficient to stabilize the relative phase. We show that the phases of the quantum states can still be aligned to, in principle, arbitrary accuracy by allowing for probabilistic operation. This is achieved by measuring the freely drifting interference of the weak phase references by a photon number resolving detector and heralding the locked states based on the detected number of photons. Interestingly, not only the phase but all other degrees of freedom are also locked.