Q 40: Quantum Information: Quantum Computing

Time: Wednesday 16:30–18:45 Location: F 128

Q 40.1 We 16:30 F 128

Quantum error correction with trapped ions — •Philipp Schindler[1], Thomas Monz[1], Julio Thomas Barreiro[1], Michael Chwalla[1], Volckmar Nebendahl[1], Markus Hennrich[1], and Rainer Blatt[1,2] — [1]Inst. f. Exphysik, Universität, Innsbruck — [2]Ins. f. Quantenoptik u. Quanteninformation, Innsbruck

We report on the experimental realization of a three-qubit quantum error-correcting code with trapped calcium ions. The implemented algorithm detects and corrects for a single-qubit phase error. The correction step is performed without any classical measurement and can therefore more easily be reapplied. The pulse sequence for this algorithm was compiled with the aid of an optimization technique resulting in a very compact sequence with a computational time similar to that of single Cirac-Zoller CNOT gate. We fully analyze the single qubit process with quantum process tomography and achieve a process fidelity of F=84(2)%.

Q 40.2 We 16:45 F 128

Processing of quantum information by linear optical systems — •Lev Plimak, Daniela Denot, and Wolfgang Schleich — Institut für Quantenphysik, Universität Ulm

We consider a series of Gedankenexperiments showing that results of any photodetection measurement performed on two optical beams originating from a beam-splitter may be imitated by a photodetection measurement performed directly on the original beam. This conclusion is further extended to an arbitrary lossless optical transformer with the number of output ports exceeding the number of input ones.

Q 40.3 We 17:00 F 128

Multiqubit Decoherence in Ion-trap Quantum Computation — •Thomas Monz[1], Philipp Schindler[1], Julio Barreiro[1], Michael Chwalla[1], Bill Coish[2,3], Markus Hennrich[1], and Rainer Blatt[1,4] — [1]Inst. f. Experimentalphysik, Innsbruck, AT — [2]Inst. f. Quantum Computing, Waterloo, CA — [3]Kavli Inst. f. Theoretical Physics, Santa Barbara, US — [4]Inst. f. Quantenoptik u. Quanteninformation, Innsbruck, AT

In a linear string of calcium ions we have realised high-fidelity Schrödinger-Cat states with more than six qubits. Fidelities exceed 95% for up to 4 ions and 88% for six ions. These high fidelities allow to investigate decoherence of highly entangled quantum states in the presence of collective dephasing, the predominant decoherence source in ion-trap quantum computation. Modelling the noise to be stationary and Gaussian, we derive and experimentally confirm a model that predicts an exponential decay of the fidelity that scales with the power of N^2 with N being the number of qubits. Such a scaling behaviour has severe effects on the applicability of quantum computation in ion-trap based quantum computation and related fields such as quantum metrology.

Q 40.4 We 17:15 F 128

Efficient manipulation of quantum systems via optimal control techniques — •Robert Fisher[1], Thomas Schulte-Herbrüggen[1], Christof Wunderlich[2], Fedor Jelezko[3], Jörg Wrachtrup[3], and Steffen Glaser[1] — [1]Department Chemie, Technische Universität München, Germany — [2]Fachbereich Physik, Universität Siegen, Germany — [3]3 Physikalisches Institut, Universität Stuttgart, Germany

We apply optimal control to the design of experiments in quantum information processing. By explicitly accounting for the experimental constraints of addressability and robustness, optimal control techniques allow for the implementation of a broader, more complex class of operations, making new experiments possible. As examples, we consider the implementation of Deutsch and Grover algorithms on two coupled ^{13}C spins at an NV center in diamond, and the preparation of multi-qubit cluster states in a system of trapped ions with a non-ideal coupling topology.

Q 40.5 We 17:30 F 128

Decomposition of nonlinear gates in finite Fock space — Seckin Sefi and •Peter van Loock — Max Planck Institute for the Science of Light

In the article of Lloyd and Braunstein (PRL, 82, 1784), a set of elementary hamiltonians is given as well as a method to simulate any continuous variable hamiltonian of bosonic modes to arbitrary precision by concatenating discrete elements. The method they presented is not constructive and for the most of the hamiltonians does not allow an exact and finite decomposition to the elementary hamiltonian set. Here, complementary to work of Lloyd and Braunstein, we discuss the potential of finite and exact decompositions of gates on occupation number Fock states in finite dimensional encoding. We show that for a finite decomposition of any logical gate on single d level qudit Fock space, a number of $d(d-1)/2+d-1$ fixed hamiltonians with an order of nonlinearity up to $3d-3$ will be sufficient.

Q 40.6 We 17:45 F 128

The fractal structure of Clifford cellular automata — •Vincent Nesme, Johannes Gütschow, and Reinhard Werner — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover

It is a well-known fact that the spacetime diagrams of some cellular automata have a fractal struc- ture: for instance Pascal*s triangle modulo 2 generates a Sierpinski triangle. Explaining the fractal structure of the spacetime diagrams of cellular automata is a much explored topic, but virtually all of the results revolve around a special class of automata, whose main features include being irreversible, being defined on an alphabet having a ring structure and respecting this structure, and fulfilling a property known as being (weakly) p-Fermat. The class of automata that we study in this article fulfills none of these properties. The cell structure is weaker, as it does not come with a multiplication, may very well be reversible *and* interesting, and they are typically far from being p-Fermat, even weakly. However, they do produce fractal spacetime diagrams, and we will explain why and how. These automata emerge naturally from the field of quantum cellular automata, as they include the classical equivalent of the Clifford quantum cellular automata, which have been studied by the quan- tum community for several reasons. They provide a universal model of quantum computation, and they can be used to generate highly entangled states, to use as a primary resourse for measurement- bases models of quatum computing.

Q 40.7 We 18:00 F 128

Symmetry in Quantum System Theory: Rules for Quantum Architecture Design — •Thomas Schulte-Herbrüggen and Uwe Sander — Technical University of Munich (TUM), Dept. Chem., Lichtenbergstrasse 4, 85747 Garching

We investigate universality in the sense of controllability and observability, of multi-qubit systems in architectures of various symmetries of coupling type and topology. By determining the respective dynamic system Lie algebras, explicit reachability sets under symmetry constraints are provided. Thus for a given (possibly symmetric) experimental coupling architecture several decision problems can be solved in a unified way: (i) can a target Hamiltonian be simulated? (ii) can a target gate be synthesised? (iii) to which extent is the system observable by a given set of detection operators? and, as a special case of the latter, (iv) can an underlying system Hamiltonian be identified with a given set of detection operators?

Finally, in turn, the absence of symmetry provides a convenient necessary condition for full controllability. Though often easier to assess than the well-established Lie-algebra rank condition, this is not sufficient unless the candidate dynamic simple Lie algebra can be preidentified uniquely. Thus for architectures with various Ising and Heisenberg coupling types we give design rules sufficient to ensure full controllability. In view of follow-up studies, we relate the unification of necessary and sufficient conditions for universality to filtering simple Lie subalgebras of su(N) comprising classical and exceptional types.

Q 40.8 We 18:15 F 128

Scalable quantum computation via local control of only two qubits — Daniel Burgarth[1,2], Koji Maruyama[2], •Michael Murphy[3], Simone Montangero[3], Tommaso Calarco[3,4], Franco Nori[2,5], and Martin B. Plenio[1,6] — [1]IMS and QOLS, Imperial College, London SW7 2PG, UK — [2]Advanced Science Institute, The Institute of Physical and Chemical Research (RIKEN), Wako-shi, Saitama 351-0198, Japan — [3]Institut für Quanteninformationsverarbeitung, Universität Ulm, D-89069 Ulm, Germany — [4]ECT*, 38050 Villazzano

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We apply quantum control techniques to control a large spin chain by only acting on two qubits at one of its ends, thereby implementing universal quantum computation by a combination of quantum gates on the latter and swap operations across the chain. It is shown that the control sequences can be computed and implemented efficiently. We discuss the application of these ideas to physical systems such as superconducting qubits in which full control of long chains is challenging.

Q 40.9 We 18:30 F 128

Go vs. no-go – potential and limitations of continuous-variable quantum computing by measurements — •Matthias Ohliger, Konrad Kieling, and Jens Eisert — University of Potsdam, 14476 Potsdam, Germany

In this talk, we will explore the feasibility of quantum computation using continuous-variable systems by means of local measurements only. In the first part of the talk, we will identify crucial limitations that arise when starting from Gaussian cluster states. This will be done by resorting to a Gaussian projected entangled pair picture as well as to notions of continuous-variable quantum repeater networks. In the second part, we will look at instances in which these limitations can be overcome, and how suitable encodings of qubits in oscillators and feasible non-Gaussian resource states give rise to universal schemes for quantum computing.