Q 63: Quanteninformation: Quantencomputer

Zeit: Freitag 14:00–16:15 Raum: VMP 6 HS-A

Q 63.1 Fr 14:00 VMP 6 HS-A

Optimal Control of Open Quantum Systems: Markovian and non-Markovian — •Thomas Schulte-Herbrüggen[1], Andreas Spörl[1], Patrick Rebentrost[2,3], Frank Wilhelm[3], and Steffen Glaser[1] — [1]Technical University Munich (TUM), 85747 Garching — [2]Harvard University, Cambridge MA, USA — [3]Institute for Quantum Computation (IQC), Waterloo, Canada

For realistic examples of Markovian and non-Markovian open quantum systems we show how optimal controls obtained numerically [1] typically cut errors by one order of magnitude [2,3,4]. The examples include spin- and pseudo-spin systems, e.g., capacitively coupled charge qubits. The setting can easily be generalised to arbitrary N-level systems. — We sketch the relation between time-optimal and relaxation-optimised controls in the light of new pictures emerging in terms of Lie semigroups [5]. — Implications for quantum CISC-compilation [6] in large systems ($\geq$100 qubits) are given as well as an outlook on how to assemble CISC modules in a decoherence-protected way.

[1] Khaneja et al., J. Magn. Reson. 172, 296-305 (2005); Schulte-Herbrüggen et al., PRA 72, 042331 (2005).
[2] Spörl et al., PRA 75, 012302 (2007)
[3] Schulte-Herbrüggen et al., quant-ph/0609037
[4] Rebentrost et al., quant-ph/0612165
[5] Dirr et al., arXiv:0811.4195
[6] Schulte-Herbrüggen et al., arXiv:0712.3227

Q 63.2 Fr 14:15 VMP 6 HS-A

Quantum gates between atoms coupled by a nano-wire — •David Dzsotjan[1,2] and Michael Fleischhauer[1] — [1]Fachbereich Physik, Technische Universität Kaiserslautern, Germany — [2]Research Institute for Particle and Nuclear Physics, XII. Konkoly-Thege ut. 29-33, H1525, Budapest, PO Box 49, Hungary

We investigate the long-range coupling of single atoms placed close to the surface of a metallic, cylindrical nanowire. Putting the emitter close to the surface of the wire, a strong Purcell effect can be observed: with very high probability, the emitter will decay into guided modes of the wire, the so-called surface plasmons [1], [2], with a rate exceeding that of free space by a large factor. The strength of the coupling originates from the fact that surface plasmon modes have an extremely small mode volume, being confined at around the surface of the nanowire. We find furthermore that there is an optimal, sub-wavelength emitter-wire distance where the coupling to the plasmon modes is maximal due to the losses originating from circulating currents. When two emitters are placed along the wire, we observe a strong, wire-mediated long-range interaction. As a result of this, super- and subradiance can occur over distances large compared to the resonant wavelength. Using this effect, one can construct quantum gates and in duce entanglement among qubits along the wire. As a specific application, we propose a scheme for constructing a phase gate by a wire-mediated interaction of two lambda atoms.

[1]. D.E. Chang, A.S. Sorensen, P.R. Hemmer, and M.D. Lukin, Phys. Rev. Lett. 97, 053002 (2006) [2]. D.E. Chang, A.S. Sorensen, P.R. Hemmer, and M.D. Lukin, Phys. Rev. B 76, 035420 (2007) [3]. A.V. Akimov, A. Mukherjee, C.L. Yu, D.E. Chang, A.S. Zibrov, P.R. Hemmer, H. Park, and M.D. Lukin, Nature 450, 402 -406 (2007) [4]. L.-W. Li, M.-S. Leong, T.-S. Yeo, and P.S. Kooi, J. Electromagn. Waves Appl. 14, 961 (2000) [5]. V.V. Klimov, M. Ducloy, Phys. Rev. A 69, 013812 (2004)

Q 63.3 Fr 14:30 VMP 6 HS-A

Demonstration of a geometric two ion/qubit phase gate on the radial modes of motion — •Thomas Huber[1], Hector Schmitz[2], Christian Schneider[1], Martin Enderlein[1], and Tobias Schaetz[1] — [1]Max-Planck-Institut für Quantenoptik — [2]LMU München

Phonons in a linear chain of ions can provide interactions/a data bus between spins/qubits for quantum simulations(QS)/computation(QC). So far, experimentalists only exploit the axial degree of freedom in linear traps, i.e. the phonons of the axial normal modes of motion. We want to open up the radial degrees of freedom, exploring the (dis)advantages with respect to QC and QS. For an increasing amount of ions it becomes, for example, more difficult to place the ions at the correct relative positions to experience identical laser phases of a standing or travelling axially propagating wave, which provides the conditional motional excitations. Pushing the ions radially renders the system insensitive to the mutual ion distance. Additionally, the frequencies of the radial modes can be adjusted to be similar. The required ground state cooling of all motional modes might hence be possible by one common cooling cycle. To calibrate our interactions for future QS, we implemented a two-qubit phase gate with a fidelity exceeding 90%. We are able to laser-cool five ions to the radial motional ground states, a first step towards simulations with increased amounts of ion spins required in QS of systems of interest, like the Bose-Hubbard Hamiltonian. It also gives perspectives to 2D lattices of spins provided in potential surface trap arrays.

Q 63.4 Fr 14:45 VMP 6 HS-A

Dynamic polarization of single nuclear spins in a room temperature diamond — •Philipp Neumann, Vincent Jacques, Johannes Beck, Fedor Jelezko, and Jörg Wrachtrup — 3. Physikalisches Institut, Universität Stuttgart, Germany

Recently, room temperature readout of single nuclear spins in diamond has been achieved by coherently mapping nuclear spin states onto the electron spin of a single NV color center. This has been the basis for spectacular experiments in quantum information science, ranging from the implementation of a nuclear-spin-based quantum register, a conditional two-qubit CNOT gate and recently the generation of Bell and GHZ states with extraordinarily long coherence times.

However, most of these experiments were performed without any deterministic polarization of nuclear spin states. This random initialization unavoidably decreases the success rate of all local operations as $1/2^N$ where N is the number of qubits.

We report a versatile method to efficiently polarize single nuclear spins in diamond, which is based on optical pumping of a single NV color center and mediated by a level-anti crossing in its excited state. A nuclear spin polarization higher than 98% is achieved at room temperature for the ^{15}N nuclear spin associated to the NV center. Furthermore we show simultaneous deterministic initialization of two nuclear spins (^{13}C and ^{15}N) close to a NV defect, which provides efficient initialization of a three qubit quantum register including the electron spin. Such robust control of nuclear spin states is a key ingredient for further scaling up nuclear-spin based quantum registers in diamond.

Q 63.5 Fr 15:00 VMP 6 HS-A

Simple quantum algorithms at room temperature using a 3-qubit register in diamond — •Johannes Beck[1], Phillip Neumann[1], Norikazu Mizuochi[2], Matthias Steiner[1], Florian Rempp[1], Vincent Jacques[1], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, D-70550 Stuttgart, Germany — [2]Graduate School of Library, Information and Media Studies, University of Tsukuba, 1-2 Kasuga, Tsukuba-City, Ibaraki 305-8550, Japan

A small quantum register in diamond consisting of a single Nitrogen-Vacancy center electron spin coupled to two ^{13}C nuclear spins has already been used to create robust multipartite entanglement in form of GHZ- and W-States at room temperature [1]. Now, focus is set upon experimental realization of elementary quantum applications, showing the feasibility of simple quantum algorithms at ambient conditions using such a quantum register. Transformation of Bell states one into another is demonstrated, corresponding to Alice's operational part in a potential superdense coding protocol. Furthermore, a report on the progress regarding implementation of Deutsch's algorithm with two qubits will be given.

[1] P. Neumann et al., *Multipartite Entanglement Among Single Spins in Diamond*, Science **320,** 1326 (2008)

Q 63.6 Fr 15:15 VMP 6 HS-A

Measurement-Based Quantum Computation in Realistic Spin-1 Chains — •Joseph M. Renes[1], Gavin Brennen[2], Stephen D. Bartlett[3], and Akimasa Miyake[4] — [1]TU Darmstadt, Germany — [2]Macquarie University, Sydney, Australia — [3]University of Sydney, Sydney, Australia — [4]Perimeter Institute, Waterloo, Canada

We study the measurement-based computational abilities of ground states of spin-1 chains near the AKLT point, as recently proposed by Brennen and Miyake [1]. In this hybrid scheme individual qubit gates

are performed by measurement while two-qubit gates are performed by dynamically coupling different chains. The gapped spectrum of the chains is expected to help suppress decoherence in realistic implementations, such as atoms or polar molecules in optical lattices. We show that the approach taken by Doherty and Bartlett to characterize the computational power of nearly-cluster state quantum computers [2] can be profitably adapted to this case, avoiding the need to keep track of the exponentially-many computational paths. Numerical analysis shows that arbitrary single-qubit operations can be faithfully executed over a reasonably wide parameter range of bilinear-biquadratic Hamiltonians near the AKLT point. Furthermore, we find that the Doherty-Bartlett approach leads directly to the use of string order parameters, showing a connection between computational questions and the traditional theoretical study of condensed matter, where these parameters arise.

[1] Brennen and Miyake, Phys. Rev. Lett. 101, 010502 (2008). [2] Doherty and Bartlett, arXiv:0802.4314v1 [quant-ph].

Q 63.7 Fr 15:30 VMP 6 HS-A

Scaling of passive quantum memories — •Fernando Pastawski, Alastair Kay, Norbert Schuch, and Juan Ignacio Cirac — Max-Planck-Institut für Quantenoptik Hans-Kopfermann-Str. 1, D-85748 Garching, Deutschland

Fault tolerance theorems state that it is possible to construct reliable (active) memories from unreliable components given resources such ass fresh ancillas. Furthermore, recent proposals claim that some many-body Hamiltonians may act as passive memories, asymptotically allowing reliable storage of quantum information. We explore different error models for such Hamiltonians and information encodings and obtain some no-go results in the absence of entropy extraction mechanisms.

Q 63.8 Fr 15:45 VMP 6 HS-A

Most quantum states are too entangled to be useful as computational resources — •David Gross[1], Steve Flammia[2], and Jens Eisert[3] — [1]Technical University of Braunschweig — [2]Perimeter Institute for Theoretical Physics, Waterloo — [3]University of Potsdam

It is often argued that entanglement is at the root of the speedup for quantum compared to classical computation, and that one needs a sufficient amount of entanglement for this speedup to be manifest. In measurement-based quantum computing (MBQC), the need for a highly entangled initial state is particularly obvious. Defying this intuition, we show that quantum states can be too entangled to be useful for the purpose of computation. We prove that this phenomenon occurs for a dramatic majority of all states: the fraction of useful n-qubit pure states is less than $\exp(-n^2)$. Computational universality is hence a rare property in quantum states. This work highlights a new aspect of the question concerning the role entanglement plays for quantum computational speed-ups. The statements remain true if one allows for certain forms of post-selection and also cover the notion of CQ-universality. We identify scale-invariant states resulting from a MERA constructrion as likely candidates for physically relevant states subject to this effect.

Q 63.9 Fr 16:00 VMP 6 HS-A

Interacting electrons, Density Functional Theory, and Quantum Merlin Arthur — •Norbert Schuch[1] and Frank Verstraete[2] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Institut für Theoretische Physik, Universität Wien, Wien, Austria

One of the central problems in quantum mechanics is to find the ground state energy of a system of electrons interacting via the Coulomb potential. Since its introduction by Hohenberg, Kohn, and Sham, Density Functional Theory (DFT) has become the most widely used and successful method for simulating systems of interacting electrons, making their original work one of the most cited in physics. In this letter, we show that the field of computational complexity imposes fundamental limitations on DFT, as an efficient description of the associated universal functional would allow to solve any problem in the class QMA (the quantum version of NP) and thus particularly any problem in NP in polynomial time. This follows from the fact that finding the ground state energy of the Hubbard model in an external magnetic field is a hard problem even for a quantum computer, while given the universal functional it can be computed efficiently using DFT. This provides a clear illustration how the field of quantum computing is useful even if quantum computers would never be built.