Q 73 Quantencomputer

Zeit: Mittwoch 14:00–16:00 Raum: HU 2002

Q 73.1 Mi 14:00 HU 2002

Coherent Manipulation of Atomic States in Dipole Potentials — •Andre Lengwenus, Michael Volk, Wolfgang Ertmer, and Gerhard Birkl — Universität Hannover, Institut für Quantenoptik, Welfengarten 1, 30167 Hannover

For the experimental realization of quantum information processing with neutral atoms, it is essential to investigate methods for the coherent manipulation of the internal states of trapped atoms. Although neutral atoms are more difficult to control than ions, they might be advantageous because of scalability and weaker coupling to the environment which might be leading to longer coherence times. For ultracold Rb85 atoms confined in optical dipole potentials, we experimentally demonstrate the coherent coupling of the hyperfine groundstates by stimulated Raman transitions. With Rabi and Ramsey techniques we investigate the dephasing of the ensemble of atoms. Applying echo spectroscopy, we measure the coherence time of the evolution of the internal states. In order to advance towards a scaleable system of qubits for quantum information processing, we apply these methods in parallel to ensembles of atoms in two-dimensional arrays of optical micro-potentials created by micro-fabricated lens arrays.

Q 73.2 Mi 14:15 HU 2002

Experimental Cluster State Quantum Computing — •Philip Walther[1], Kevin Resch[1], Terry Rudolph[2], Emmanuel Schenck[1], Harald Weinfurter[3], Markus Aspelmeyer[1], and Anton Zeilinger[1,4] — [1]Institut für Experimentalphysik, Universität Wien, Boltzmanngasse 5, 1090 Vienna, Austria — [2]QOLS, Blackett Laboratory, Imperial College London, London SW7 2BW, United Kingdom — [3]LMU München, Sektion Physik,Schellingstraße 4/III, D-80799 München — [4]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Boltzmanngasse 3, 1090 Vienna, Austria

We have experimentally realized four-qubit cluster states encoded into the polarization state of four photons, in which each qubit can be individually addressed. Very recently, these cluster states haven been proposed as a new architecture for quantum computation, which requires the quantum computer to be initialized in such a highly-entangled cluster state. From this point, the quantum computation proceeds by a sequence of single-qubit measurements with classical feedforward of their outcomes. Because of the essential role of measurement this quantum computer is irreversible and thus one-way. In the one-way quantum computer the order and choices of measurements determine the algorithm computed. We fully characterize the quantum state by implementing the first experimental four-qubit quantum state tomography and explore the state's relevant entanglement properties. Using this cluster state we perform the first demonstration of one-way quantum computing through a universal set of one- and two-qubit operations.

Q 73.3 Mi 14:30 HU 2002

Process Tomography of a nuclear quadrupolar spin quantum information processor — •Hermann Kampermann — Universität Düsseldorf

In the present work the first virtual 2 qubit solid state NMR quantum processor, using the spin-$\frac{3}{2}$ Na nuclei of a $NaNO_3$ single crystal, is presented. Methods from liquid NMR, like strongly modulating pulses, are adopted to the quadrupolar spin system to implement efficient unitary operations and to generate pseudo pure states. The procedure of quantum process tomography was developed for the quadrupolar spin system, which is used to characterize quantum algorithms and the decoherence process.

Q 73.4 Mi 14:45 HU 2002

Optimizing linear optics quantum gates — •Jens Eisert — Institut für Physik, Universität Potsdam, 14469 Potsdam, Germany — Blackett Laboratory, Imperial College London, London SW7 2BW, UK

In this talk, the problem of finding optimal success probabilities of static linear optics quantum gates is linked to the theory of convex optimization. The success probability is a key quantity that determines on the one hand the necessary significant overhead in resources in near-deterministic quantum computation using linear optics. On the other hand, in small-scale linear optical applications one may be well-advised in any case to make use of postselected quantum gates. It is shown that by exploiting this link to convex optimization, upper bounds for the success probability of networks realizing single-mode gates can be derived, which hold in generality for linear optical networks followed by postselection, i.e., for networks of arbitrary size, any number of auxiliary modes, and arbitrary photon numbers. As a corollary, the previously formulated conjecture is proven that the optimal success probability of a postselected non-linear sign shift gate is $p = 1/4$, a gate playing the central role in the scheme of Knill-Laflamme-Milburn for linear optics quantum computation. The concept of Lagrange duality is shown to be applicable to provide rigorous proofs for such bounds for elementary gates without feed-forward, although the original problem is a difficult non-convex problem in infinitely many objective variables. Similar applications of this method in finding optimal linear optical schemes are outlined.
[1] J. Eisert, quant-ph/0409156.

Q 73.5 Mi 15:00 HU 2002

Quantum computing with single spins in diamond — •Torsten Gaebel, Iulian Popa, Michael Domhan, Christoffer Wittmann, Fedor Jelezko, and Jörg Wrachtrup — 3. Physikalisches Institut Universität Stuttgart

Long decoherence time and a precise understanding and manipulation of state evolution are some of the most important requirements to be met by a quantum system in order to implement quantum computing algorithms. An efficient system for this purpose is given by single paramagnetic defect centers in diamond. Recently, single spin readout in nitrogen-vacancy (N-V) defects in diamond at low temperature was demonstrated [1]. The coherent evolution of the electron spin of a defect center in diamond was previously reported [2] and a two-qubit conditional quantum gate at ambient conditions was demonstrated [3].

To scale up the number of qubits, two or more N-V centers can be coupled via their magnetic dipolar interaction. Because of the weakness of the magnetic dipoles, the separation distance between two defects should be in the range of a few nanometers. We will show the first data on N-V centers created by specific implantation techniques, allowing for short inter-center distances. Coherent coupling between implanted defects was demonstrated using spin echo modulation techniques.

[1] F. Jelezko, I. Popa, A. Gruber, and J. Wrachtrup, Appl. Phys. Lett. 81, 2160 (2002). [2] F. Jelezko, T. Gaebel, I. Popa, A. Gruber, and J. Wrachtrup, Phys. Rev. Lett. 92, 076401 (2004). [3] F. Jelezko, T. Gaebel, I. Popa, M. Domhan, A. Gruber, and J. Wrachtrup, Phys. Rev. Lett. 93, 130501 (2004).

Q 73.6 Mi 15:15 HU 2002

Coherent control of trapped ions using off-resonant lasers — •Juan Jose Garcia Ripoll[1], Peter Zoller[2,3], and Juan I. Cirac[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, Garching bei München, D-85748 — [2]Institute for Theoretical Physics, University of Innsbruck, A-6020 Innsbruck, Austria — [3]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, A-6020 Innsbruck, Austria

In this work we develop a unified framework to study the coherent control of trapped ions subject to state-dependent forces. Taking different limits in our theory, we can reproduce two different designs of a two-qubit quantum gate —the pushing gate [1] and the fast gates based on laser pulses from [2]—, and propose a new design based on continuous laser beams. We demonstrate how to simulate Ising Hamiltonians in a many ions setup, and how to create highly entangled states and induce squeezing. Finally, in a detailed analysis we identify the physical limits of this technique and study the dependence of errors on the temperature.

[1] J. I. Cirac and P. Zoller, Nature 404, 579-581 (2000).

[2] J. J. Garcia-Ripoll, P. Zoller and J. I. Cirac, Phys. Rev. Lett. 91, 157901 (2003).

Q 73.7 Mi 15:30 HU 2002

Verschränkte Ionenzustände mit einer Lebensdauer von mehr als zehn Sekunden — •W. Hänsel[1,2], C. Roos[1], H. Häffner[1,2], M. Riebe[1], M. Chwalla[1], J. Benhelm[1], T. Körber[1], G. Lancaster[1], D. F. V. James[3], F. Schmidt-Kaler[1,4] und R. Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Österreich — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Österreich — [3]Los Alamos National Laboratory, NM 87545, Los Alamos, USA — [4]Abteilung Quanten-Informationsverarbeitung,Universität Ulm, Albert Einstein Allee 11, D-89069 Ulm

Es wird häufig angenommen, dass die quantenmechanische Verschränkung zweier räumlich weit getrennter Teilchen ein besonders empfindlicher Zustand ist und aufgrund der Wechselwirkung mit äußeren Feldern sehr schnell zerfällt. In einer Ionenfalle ist es gelungen, ein Paar von Kalzium^{40}-Ionen so zu verschränken, dass der resultierende Zustand besonders geschützt ist. Die Nutzung eines dekohärenzfreien Unterraums ermöglicht dem erzeugten Bell-Zustand eine Lebensdauer von über zehn Sekunden, eine Zeit, die viele Größenordnungen über der Zeit einer einzelnen Gatteroperation liegt. In einem Quantencomputer können daher solche dekohärenzfreien Unterräume für robuste Speicher genutzt werden, darüber hinaus ermöglichen sie den geschützen Transport quantenmechanischer Information.

Q 73.8 Mi 15:45 HU 2002

Prozesstomografie einer Teleportation — •H. Häffner[1,2], M. Riebe[1], C. Roos[1], W. Hänsel[1], M. Chwalla[1], J. Benhelm[1], T. Körber[1], G. Lancaster[1], D. F. V. James[3], F. Schmidt-Kaler[1,4] und R. Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Österreich — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie derWissenschaften, Österreich — [3]Los Alamos National Laboratory, NM 87545, Los Alamos, USA — [4]Abteilung Quanten-Informationsverarbeitung,Universität Ulm, Albert Einstein Allee 11, D-89069 Ulm

Drei ^{40}Ca-Ionen werden in einer linearen Paul-Falle gespeichert und die in ihnen gespeicherte Quanteninformation wird mittels Laserpulsen gezielt manipuliert. Das Teleportationsexperiment verläuft wie folgt: Ziel- und Hilfsion werden verschränkt und anschliessend wird das Quellion in einem von sechs verschiedenen Eingangszuständen präpariert. Das Ergebnis einer Bellmessung an Hilfs- und Quellion bestimmt welche Laserpulse zur Rekonstruktion des Eingangzustandes am Zielion eingestrahlt werden müssen. Die Messung der Dichtematrix des teleportierten Zustands für alle sechs Eingangszustände erlaubt dann die Bestimmung der Prozessmatrix χ, die den Teleportationsprozess vollständig beschreibt.

[1] M. Riebe *et al*, "Deterministic quantum teleportation with atoms", Nature **429**, 734 (2004).