# Q 57: Quanteninformation (Quantencomputer II)

Zeit: Donnerstag 14:00–16:15 Raum: 5L

**Gruppenbericht** Q 57.1 Do 14:00 5L

**Theoretical and experimental challenges for the trapped electron quantum computer** — •Irene Marzoli[1], Pavel Bushev[8], Adam Buczek[6], Michael Hellwig[8], Carsten Henkel[5], Igor Jex[7], Wojtek Koczorowski[6], Vojtěch Košťák[7], Gerrit Marx[2], Riccardo Natali[1], Ferdinand Schmidt-Kaler[8], Ewa Stachowska[6], Stefan Stahl[4], Gustaw Szawioła[6], Adrian Walaszyk[6], Paolo Tombesi[1], and Günter Werth[3] — [1]University of Camerino, Italy — [2]Universität Greifswald — [3]Universität Mainz — [4]Stahl Electronics, Mettenheim — [5]Universität Potsdam — [6]Poznan University of Technology, Poland — [7]Czech Technical University, Prague — [8]Universität Ulm

One of the possible candidates for a quantum computer is an array of trapped electrons [1]. The traps can be realized with segmented ring electrodes deposited on a planar substrate, combined with a homogeneous magnetic field (Penning traps). Since the first proposal [2], quite a number of additional investigations and studies of this scalable scheme have been performed. Currently some of the elements of this scheme are entering the experimental stage. On the theoretical side, we comment on single qubit coherence, coupling qubits with wires, implementation of Heisenberg spin chains, and quantum networks. Relevant experimental implications are outlined.

[1] G Ciaramicoli & al, Phys Rev Lett **91** (2003) 017901
[2] S Stahl & al, Eur Phys J D **32** (2005) 139

Q 57.2 Do 14:30 5L

**Efficient algorithm for multi-qudit twirling for ensemble quantum computation** — •Geza Toth[1] and Juan Jose Garcia-Ripoll[2] — [1]Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, P.O. Box 49, H-1525 Budapest, Hungary — [2]Max Planck Institute for Quantum Optics, Hans-Kopfermann-Strasse 1, D-85748 Garching, Germany

We present an efficient algorithm for twirling a multi-qudit quantum state. The algorithm can be used for approximating the twirling operation in an ensemble of physical systems in which the systems cannot be individually accessed. It can also be used for computing the twirled density matrix on a classical computer. The method is based on a simple non-unitary operation involving a random unitary. When applying this basic building block iteratively, the mean squared error of the approximation decays exponentially. In contrast, when averaging over random unitary matrices the error decreases only algebraically. We present evidence that the unitaries in our algorithm can come from a very imperfect random source or can even be chosen deterministically from a set of cyclically alternating matrices. Based on these ideas we present a quantum circuit realizing twirling efficiently.

Q 57.3 Do 14:45 5L

**Experimental realization of quantum search algorithm using hyper-entanglement** — •Kai Chen[1], Cheming Li[1], Qiang Zhang[1], Alois Mair[1], Yu-Ao Chen[1], Alexander Goebel[1], Shuai Chen[1], Joerg Schmiedmayer[1], and Jian-Wei Pan[1,2] — [1]Physikalisches Institut der Universitaet Heidelberg, Philosophenweg 12, Heidelberg 69120, Germany — [2]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China

We present the first experimental demonstration of an one-way implementation of Grover search algorithm by exploiting optical hyper-entangled cluster states. This is realized by developing a bright two photon hyper-entangled source with both polarizing and spacial degrees of freedom, which achieves the fastest quantum search utilizing measurement-based quantum computation in currently available optical setups. The two qubit algorithm is succeeded within one single step, in wonderful agreement with theoretical predictions. This highlights ultra-fastness and simplicity of one-way quantum computing using optical hyper-entangled cluster states.

Q 57.4 Do 15:00 5L

**Quantum processing photonic states in optical lattices** — •Christine Muschik, Ines de Vega, Diego Porras, and Ignacio Cirac — Max Planck Institute for Quantumoptics, Garching, Germany

The mapping of photonic states to collective excitations of atomic ensembles is a powerful tool which finds a useful application in the realization of quantum memories and quantum repeaters. In this work we show that cold atoms in optical lattices can be used to perform an entangling unitary operation on the transferred atomic excitations. After the release of the quantum atomic state, our protocol results in a deterministic two qubit gate for photons. The proposed scheme is feasible with current experimental techniques and robust against the dominant sources of noise.

Q 57.5 Do 15:15 5L

**High-speed linear optics quantum computing using active feed-forward** — •Robert Prevedel[1], Philip Walther[1,2], Felix Tiefenbacher[1,3], Pascal Böhi[1], Rainer Kaltenbaek[1], Thomas Jennewein[3], and Anton Zeilinger[1,3] — [1]Institute for Experimental Physics, University of Vienna, Boltzmanngasse 5, A-1090 Vienna, Austria — [2]Physics Department, Harvard University, Cambridge, Massachusetts 02138, USA — [3]Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Boltzmanngasse 3, A-1090 Vienna, Austria

Quantum computers promise to be more efficient and powerful than their classical counterparts. In the one-way quantum computer model, a sequence of measurements processes qubits, which are initially prepared in a highly entangled cluster state. The key advantage of this scheme over the standard network approach of quantum computing is that inherent, randomly induced measurement errors can classically be fed-forward and corrected by adapting the basis of subsequent measurements. Active feed-forward is therefore crucial to achieve deterministic quantum computing once a cluster state is prepared. We have experimentally realized such a feed-forward one-way quantum computation scheme by employing up to three active-switching Electro-Optical Modulators (EOM) in a four-qubit cluster state encoded into the polarization state of four photons. Using these switches we demonstrate one- and two-qubit gate operations as well as Grover's quantum search algorithm. With present technology this feed-forward step can be performed in less than 150 nanoseconds.

Q 57.6 Do 15:30 5L

**"Entanglement Swapping" mit gespeicherten Ionen** — •T. Monz[1], M. Riebe[1], P. Schindler[1], M. Chwalla[1], K. Kim[1], P. O. Schmidt[1], W. Hänsel[1], H. Häffner[2], C. F. Roos[2] und R. Blatt[1,2] — [1]Institut für Experimentalphysik, Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Innsbruck, Austria

Einzeln adressierbare Ionen, gefangen in einer Paul-Falle, stellen einen vielversprechenden Kandidaten für die Realisierung eines Quantencomputers dar. Ein wichtiger Baustein ist ein verschränkendes 2-Qubit-Gatter, in unserem Fall ein Cirac-Zoller controlled NOT-Gatter. Mit Hilfe dieses Gatters konnten wir bereits die Teleportation des elektronischen Zustandes eines Ionenqubits auf ein anderes Ion implementieren. "Entanglement Swapping" stellt eine verallgemeinerte Form dieser Teleportation dar, bei der ein verschränktes Qubit teleportiert wird. Im Vortrag wird auf die apparativen Verbesserungen eingegangen welche die Implementierung solcher fortgeschrittenen Algorithmen erlauben. Erste Messungen zur Realisierung von "Entanglement Swapping" werden präsentiert.

Q 57.7 Do 15:45 5L

**Percolation, renormalization, and quantum computing with non-deterministic gates** — •Konrad Kieling[1,2], Terry Rudolph[1,2], and Jens Eisert[1,2] — [1]QOLS, Blackett Laboratory, Imperial College London, Prince Consort Road, London SW7 2BW, UK — [2]Institute for Mathematical Sciences, Imperial College London, Prince's Gate, London SW7 2PE, UK

We apply a notion of static renormalization to the preparation of cluster states for quantum computing, exploiting ideas from percolation theory. Such a strategy yields a novel way to cope with the randomness of non-deterministic quantum gates. This is most relevant in the context of linear optical architectures, where probabilistic gates are inevitable. We demonstrate how to efficiently construct cluster states without the need for rerouting, thereby avoiding a massive amount of feed-forward and conditional dynamics, and furthermore show that except for a single layer of fusion measurements during the prepa-

ration, all further measurements can be shifted to the final adapted single qubit measurements. Remarkably, the cluster state preparation is achieved using essentially the same scaling in resources as if deterministic gates were available. Further, techniques to reduce the size of the required resource states will be presented.

Q 57.8 Do 16:00 5L

**Quantum gates for optical transition qubits in ion trap** — •Kihwan Kim[1], Mark Riebe[1], Michael Chwalla[1], Thomas Monz[1], Philipp Schindler[1], Hartmut Häffner[2], Christian Roos[2], Wolfgang Hänsel[1], Timo Körber[2], Piet Schmidt[1], and Rainer Blatt[1,2] — [1]Institute für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Austria

Qubits in ion trap quantum computation have been implemented at the long lived atomic states of either micro wave transitions or optical transitions. To realize a controlled-NOT gate, quantum gate operations have been studied theoretically and experimentally that use spin-dependent forces on hyperfine qubits. For qubits encoded in optical transitions, however, only controlled-NOT gates of Cirac-Zoller have been investigated so far [1,2]. Here, we show that similar forces to spin dependent one can also be employed for qubits on optical transitions. In contrast to hyperfine qubits, we find that the forces on optical quadrupole transitions have the following interesting properties: (1) Spontaneous photon scattering rates are low, (2) $\sigma_z$ spin dependent forces can be be applied to magnetic-field insensitive states, (3) maximum coupling strength is achieved in a pair of co-propagating laser beams, which makes the gate robust against phase errors from optical path length fluctuations. We discuss the physics behind the gate operation and discuss its sensistivity against experimental imperfections.

[1] F. Schmidt-Kaler, *et al.*, Nature **422**, 408 (2003).
[2] M. Riebe, *et al.*, Phys. Rev. Lett. **97**, 220407 (2006).