Q 28: Poster Quanteninformation

Zeit: Dienstag 16:30–19:00 Raum: Poster C2

Q 28.1 Di 16:30 Poster C2

Adaptive Estimation of Qubits by Linear Optical Measurements — •Christof Happ and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, 89069 Ulm

Optical measurement methods for the estimation of an unknown qubit, of which only a limited number N of copies is available, are discussed. The studied methods compare a single copy of the unknown state $|\psi\rangle$ to an arbitrary ruler state $|r_\nu\rangle$ by beam splitter measurements. Using Monte Carlo simulations, schemes for estimating $|\psi\rangle$ as well as for adapting a reference state $|r_\nu\rangle$ for further measurements on remaining copies of $|\psi\rangle$ were investigated. We present simulation results assessing the quality of estimation by the average fidelity $\left|\langle\psi|\psi_N^{\text{est}}\rangle\right|^2$ between unknown and finally estimated state $\left|\psi_N^{\text{est}}\right\rangle$.

Q 28.2 Di 16:30 Poster C2

Dephasing of two Qubits — •Julius Helm and Walter T. Strunz — Theoretical Quantum Dynamics, Institute of Physics, University of Freiburg, Hermann-Herder-Strasse 3, 79104 Freiburg, Germany

We study quantum channels applied to systems of two qubits that may be described in terms of stochastically fluctuating classical fields (so-called random external fields or REF). For arbitrary pure initial states we examine the sensitivity of purity and entanglement of the composite quantum system when subject to dephasing channels, i.e., dissipationless quantum channels. With concurrence as entanglement measure we are able to identify certain accessible regions in the purity-concurrence diagram, generalizing results obtained for local unital channels [1]. Furthermore, we identify a class of initial states that are robust against disentanglement when only dephasing channels acting on both qubits simultaneously are involved.

[1] Ziman, M and Bužek, V, "Concurrence vs. purity: Influence of local channels on Bell states of two qubits", Phys. Rev. A 72, 052325 (2005)

Q 28.3 Di 16:30 Poster C2

Effect of local operations on entanglement-induced state ordering of two qubits — •Lars Erik Würflinger and Walter T. Strunz — Theoretical Quantum Dynamics, Institute of Physics, University of Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg

Any measure of entanglement E induces an ordering of states. Local operations on a bi-partite quantum system cannot create entanglement; but in what way do they affect the ordering of states? Focussing on the two qubit case we find that there are no unital local channels that preserve the ordering for all states, with unitary and entanglement breaking channels being the only (trivial) exceptions, as has been conjectured by Ziman and Buzek [1]. However, when restricted to certain one-parameter families of states such as Werner states, or pure states, ordering based on concurrence is preserved under all local unital channels. We therefore investigate in more detail to what extend entanglement-induced state ordering is preserved for a restricted class of states (or channels).

[1] M. Ziman and V. Bužek: *Entanglement-induced state ordering under local operations*, Phys. Rev. A **61**, 012312 (2006).

Q 28.4 Di 16:30 Poster C2

A planar Paul trap — •Robert Matjeschk, Christian Schneider, Hector Schmitz, Axel Friedenauer, Jan Glückert und Tobias Schätz — MPI für Quantenoptik, Hans-Kopfermann Str. 1, 85748 Garching

In recent years, along with the idea of quantum-computing, the concept of quantum-simulations arose. This is considered to be a new approach to investigate the dynamics of quantum many-body systems in nature. A promising realization is the simulation based on trapped ions, in particular in Paul traps. Besides the principle study of feasibility, an important issue is scalability - the possibility to confine and control many ions. A magnitude of 100 to 1000 ions is supposed to lead to new insight into quantum many-body dynamics.

In linear traps this scalability is hindered by the fact that all ions are trapped in one effective oscillator potential. This leads for example to a non-homogeneous distance distribution and thus to a non-homogeneous interaction strength distribution between the ions. Also in such assemblies only one dimensional systems could be simulated.

We are developing a 2D-surface-trap where each ion is confined in its own effective oscillator potential, while the (homogeneous) distance between the ions is still small enough (30-50 μm) to maintain a non-negligible ion-ion interaction (mediated by coulomb forces). The ions will be aranged in a two-dimensional plane, adressing yet unsolved two-dimensional problems like spin frustration in 2D lattices.

Q 28.5 Di 16:30 Poster C2

Techniques minimizing noise in a quantum simulation using trapped Mg ions — •Jan Tibor Glückert — Max-Planck-Institut für Quantenoptik, Garching, Deutschland

Creating a robust experimental setup is a essential task for experiments in the quantum regime e.g. quantum simulation. Disturbing effects before and during a quantum simulation must be minimized in order to reach a suitable fidelity. In a quantum simulation using Mg ions in a linear Paul trap we were confronted with three types of disturbance mainly. Thermal motion of the ions is a handicap for gaining high precision in the most experiments but a knock-out criterion for experiments which require knowledge of the system's exact motional state. Furthermore the radio-frequency fields used to confine the ions in the trap can lead to periodical motion of the ions (so called micromotion) which can be responsible for further heating effects. The third effect originates in fluctuations of the ion's energy levels itself. Induced by Zeeman effect these level follow (periodical) disturbance in the applied magnetic fields. We present the impact of these effects on a feasibility study on quantum simulation and techniques to cope with them. Namely, these techniques are first and second sideband cooling to ground state ($\bar{n} < 0.05$), a procedure minimizing micromotion and a setup reducing magnetic field fluctuation.

Q 28.6 Di 16:30 Poster C2

Quantum Information Processing with Atoms in Arrays of Dipole Potentials — •Malte Schlosser, Jens Kruse, Andre Lengwenus, Christian Gierl, Joost Sattler, and Gerhard Birkl — Institut für Angewandte Physik, TU Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt

Quantum information processing with neutral atoms represents an important experimental approach complementing systems based on trapped ions. Especially the question of scalability might be easier addressed in the case of neutral atoms. By using ultra-cold atoms in optical dipole traps, one can realize highly controllable systems with long coherence times. In our experiment, we use two-dimensional arrays of optical micro-potentials created by micro-fabricated lens arrays as the architecture for a scalable quantum proecessor. Due to the large lateral separation of neighboring potential wells, each trap is individually addressable. For the qubit manipulation, we apply coherent Raman coupling to the hyperfine ground states of small ensembles of ^{85}Rb atoms. We demonstrate the transport of atoms from one trap position to another which is needed for a realization of a two-qubit gate based on ultracold collisions. The scalability of this transport process up to macroscopic distances is shown by performing a repeated hand over of atoms from trap to trap. We present investigations of the coherence of the system using Ramsey and spin-echo methods and observe nearly no loss of coherence while moving the atoms.

We give a detailed overview of the experimental configuration, the experiments performed, and the results obtained.

Q 28.7 Di 16:30 Poster C2

Quantum cryptography with qudits using one- and two-way entanglement purification — •Kedar Ranade and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt

Well-known quantum cryptographic protocols can be generalised to qudits, i. e. to d-dimensional quantum systems. We analyse the security of these protocols using entanglement purification involving one-way and two-way classical communication, focussing on protocols which can be reduced to practically feasible prepare-and-measure schemes. We further attempt to provide precise bounds for the maximally tolerable error rates of these protocols using generic methods to determine such bounds.

Q 28.8 Di 16:30 Poster C2

Towards Einstein-Podolsky-Rosen quantum channel multiplexing — •Aiko Samblowski, Boris Hage, and Roman Schn-

abel — Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstraße 38, 30167 Hannover, Germany

We present an experiment to utilize a single broadband squeezed field as a source for a large number N of quantum channels, based on distributed Einstein-Podolsky-Rosen (EPR) entangled states. Each of those channels can serve as a resource for independent quantum communication protocols. N-fold channel multiplexing can be realized by accessing $2N$ squeezed modes at different Fourier frequencies of a single squeezed field. We demonstrate the experimental implementation of the $N = 1$ case through the interference of two squeezed modes.

Q 28.9 Di 16:30 Poster C2

Fiber based Quantum Cryptography with Continuous Variables — •Josef Fürst[1], Carlos H. Wiechers M.[1,3], Dominique Elser[1], Christoffer Wittmann[1], Ulrik L. Andersen[1,2], and Gerd Leuchs[1] — [1]Institut für Optik, Information und Photonik, Max-Planck-Forschungsgruppe, Universität Erlangen-Nürnberg, Günther-Scharowsky-Str. 1 / Bau 24, 91058 Erlangen, Germany — [2]Department of Physics, Technical University of Denmark, Building 309, 2800 Kgs. Lyngby, Denmark — [3]Instituto de Física de la Universidad de Guanajuato, Lomas del Bosque 103, 37150 León, Guanajuato, Mexico

Quantum Key Distribution (QKD) offers a secure method of sharing a secret key between two parties, commonly called Alice and Bob. In general, there are two different kinds of QKD protocols either with discrete variables or with continuous variables. We implement a continuous variable protocol with binary encoded coherent states, which offers convenient state preparation and measurement. No entanglement source is present in our prepare and measure scheme. However, the nonorthogonality of the signal states, encoded by discrete phase and amplitude modulation, leads to effective entanglement [1]. The encoded states (ES) and the Local Oscillator (LO) are sent from Alice to Bob via a single optical fiber using time multiplexing. Thereby, scattering from the LO into the ES, which generates noise, is prevented. Subsequently, we measure both conjugate quadratures of the ES by homodyne detection and generate the raw key using postselection.

[1] S. Lorenz et al., Phys. Rev. A 74, 042326 (2006)

Q 28.10 Di 16:30 Poster C2

Free Space Quantum Key Distribution with Coherent Polarization States — •Tim Bartley[1], Dominique Elser[1], Christoffer Wittmann[1], Ulrik L. Andersen[1,2], and Gerd Leuchs[1] — [1]Institut für Optik, Information und Photonik (Max-Planck-Forschungsgruppe), Universität Erlangen-Nürnberg, Günther-Scharowsky-Str. 1, Bau 24, 91058 Erlangen — [2]Department of Physics, Technical University of Denmark, Building 309, 2800 Kgs. Lyngby, Denmark

Quantum key distribution (QKD) is the process of establishing a secret shared key between two parties, traditionally named Alice and Bob. The security is based on the laws of quantum mechanics, in contrast to classical schemes, where security relies only on unproven mathematical assumptions.

In our free space QKD setup we encode the signal in coherent states which allow for convenient and fast state preparation and measurement. We utilize a pair of conjugate polarization variables (Stokes parameters) as signal carriers. This produces an excellent interference between signal and local oscillator without the need for stabilization. After the successful demonstration of this QKD scheme in the laboratory [1], we now present a proof-of-principle experiment under real free space conditions: the quantum states are transmitted over 100 m on the roof of our institute's building. The use of a retro-reflector enables us to place Alice's and Bob's station on the same optical table. In the future, we plan to establish a QKD link between two distinct buildings 1.5 km apart.

[1] S. Lorenz et al., Phys. Rev. A **74**, 042326 (2006).

Q 28.11 Di 16:30 Poster C2

QKD Decoy Protocol with Photon Number Measurement — •Malte Avenhaus[1], Wolfgang Mauerer[1], Patrick Bronner[2], and Christine Silberhorn[1] — [1]Max Planck Research Group IOIP, Günther-Scharowsky-Str. 1 / Bau 24, 91058 Erlangen — [2]Friedrich-Alexander-Universität Erlangen Nürnberg, Staudtstr. 7, 91058 Erlangen

Quantum decoy protocols provide an advantageous alternative to various conventional QKD protocols. Decoy protocols feature a lower threshold for detecting a potential eavesdropper and thus increase the secure communication distance. The principle of operation is that Alice uses photons as quantum carriers and interposes a decoy photon distribution within the signal.

We investigate the experimental implementation of a decoy protocol. On Alice's side, a pulsed laser beam pumps a PDC process in a PPKTP wave-guide. The PDC process shows high source brightness and converts photons from the pump mode at 1550nm in signal and idler mode of 800nm and 1550nm respectively. The signal mode is particularly apt for photon number measurements on Alice's side, whereas the idler mode is used for low loss transmission via telecommunication fibre to recipient Bob. The decoy subset during communication may be chosen a posteriori while performing a classical communication.

Q 28.12 Di 16:30 Poster C2

Spectral effects in Quantum Key Distribution — •Wolfram Helwig, Wolfgang Mauerer, and Christine Silberhorn — University Erlangen-Nuremberg, Max-Planck Research Group IOIP, Integrated Quantum Optics Group

In recent years tremendous research progress was made in the field of quantum key distribution (QKD). By now a variety of protocols exists for which security has been proven even for realistic imperfect devices. The proofs based on the idea of Shor and Preskill, provide us with a lower bound on the secure key generation rate. The security of BB84 relies on the fact, that well defined single-mode photonic states are prepared by the sender and used as information carriers. However, potential sources for QKD implementations like parametric down conversion (PDC) sources emit states with a multi-mode spectral distribution. These states have to be described in a higher-dimensional Hilbert space. We investigate to what extent these spectral properties affect the security considerations.

We further present a comparison of the theoretical bounds on the secure key rates for different protocols and the dependence on various experimental imperfections, e.g., dark-counts, detector efficiency, channel attenuation etc. Only single-photon signals contribute to the secure key, but unfortunately such sources don't exist at present. Hence we consider different photon statistics in our simulations.

Q 28.13 Di 16:30 Poster C2

Beyond the three-partite GHZ and W states using a bimodal cavity — •Denis Gonta[1], Thomas Radtke[2], and Stephan Fritzsche[1,3] — [1]Max–Planck–Institut für Kernphysik, Postfach 103980, D–69029 Heidelberg — [2]Institut für Physik, Universität Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel — [3]Physikalisches Institut der Universität Heidelberg, Philosophenweg 12, D-69120 Heidelberg

In the framework of cavity QED, we propose two novel schemes to engineer the four-partite entangled GHZ and W states. The entangled states are produced between the two-level Rydberg atoms in a deterministic way. In contrast to standard (single-mode) cavity schemes, our proposal is based on a *bimodal* cavity that possesses two independent modes of the light field. In addition, we suggest two schemes to reveal the non-classical correlations of the entangled states and to ensure that no statistical (uncorrelated) mixtures of states have been produced. An extension of the schemes to produce N-partite entangled GHZ and W states is also possible.

Q 28.14 Di 16:30 Poster C2

Wigner-Ionenkristalle für Quanteninformationsverarbeitung — •Jens Baltrusch[1], Jacob Taylor[2] und Tommaso Calarco[1] — [1]Institut für Quanteninformationsverarbeitung, Universität Ulm, 89079 Ulm — [2]Department of Physics, Massachusetts Institute of Technology, Cambridge, MA 02139

In einer Penningfalle gefangene Ionen formieren sich bei geeignet gewählten Fallenparametern und Temperaturen zu 2D- oder 3D-Wigner-Kristallen. Typische Ionenabstände in einem solchen Wigner-Kristall sind in der Größenordnung von 10 μm, so dass Adressierung und Quantenkontrolle einzelner Ionen mit Hilfe von stark fokussierten Lasern realisierbar sind. Weiter sind bei thermischen Phononenanregungen robuste Zwei-Qubit-Quantengatter genauso implementierbar wie hochverschränkte Zustände, sogenannte Cluster-States, so dass dieses System ein vielversprechenden und skalierbaren Zugang für zahlreiche Anwendungen in der Quanteninformationsverarbeitung bietet.

Der Schwerpunkt unserer theoretischen Untersuchungen liegt dabei in der Bestimmung der für eine experimentelle Umsetzung geeigneten Übergänge und Laserkonfigurationen, um insbesondere eine möglichst hohe Genauigkeit der Gatteroperationen bei gleichzeitig kurzen Gatterzeiten zu erzielen. Offene Fragestellungen betreffen unter anderem die Ausweitung bisheriger Konzepte auf 3D-Kristalle sowie den Einfluß der Zyklotronbewegung auf die Genauigkeit und Stabilität der implementierten Gatter.

Q 28.15 Di 16:30 Poster C2

Towards long distance atom-atom entanglement — •Wenjamin Rosenfeld[1], Florian Henkel[1], Michael Krug[1], Christian Jakob[1], Andreas Deeg[1], Fredrik Hocke[1], Jürgen Volz[1], Markus Weber[1], and Harald Weinfurter[1,2] — [1]Fakultät für Physik der LMU, 80799 München — [2]Max-Planck Institut für Quantenoptik, 85748 Garching

Entanglement is a central part of quantum information and communication applications. Of special interest is entanglement between different quantum objects like photons and atoms. It allows to combine the advantages of long atomic coherence times with the ability of photons to transport quantum information over large distances.

In our experiment we generate entanglement between the spin of a single optically trapped Rb87 atom and the polarization of a photon in a spontaneous decay process in a lambda-type transition[1]. Based on this entanglement we performed a first demonstration of a quantum communication protocol between an atomic qubit and a photonic communication channel[2]. More recently we have demonstrated faithful distribution of entanglement over a 300 m long optical fiber. Here we report on the realization of a second atom trap and on the progress towards generating entanglement between two distant atoms via entanglement swapping.

[1] J. Volz et al., PRL 96, 030404 (2006)
[2] W. Rosenfeld et al., PRL 98, 050504 (2007)

Q 28.16 Di 16:30 Poster C2

Single-Atom Single-Photon Quantum Interface — •Tatjana Wilk[1], Simon C. Webster[1], Axel Kuhn[2], and Gerhard Rempe[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching — [2]Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, UK

Atom-cavity systems with the ability to generate single photons provide an ideal toolbox for quantum networks. Atoms stored in an intracavity dipole trap act as quantum memories, whereas photons can be used to interconnect distant atom-cavity nodes. The cavity provides an interface between the stationary and flying qubits that boosts the overall efficiency of single photon generation compared to freespace, thus allowing quantum state transfer from a single atom onto a single photon [1]. This is demonstrated by entangling a single atom with a single photon emitted into the cavity mode and subsequently mapping the quantum state of the atom onto a second photon. The latter step disentangles the atom from the light and results in an entangled photon pair. [1] Wilk et al., *Science* **317**, 488 (2007).

Q 28.17 Di 16:30 Poster C2

Observing Free-Space and Cavity Emission of one Atom in a High-Finesse Optical Cavity — •Holger Specht, Bernhard Weber, Tobias Müller, David Moehring, and Gerhard Rempe — Max-Planck-Institute for Quantum Optics, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany

Using state of the art trapping techniques and cavity cooling schemes we are able to trap a single neutral atom inside a high-finesse cavity for several tens of seconds. In [1] we showed that our coupled atom-cavity system can be used to generate single photons in a controlled way. With our long trapping times and a single-photon production efficiency of 9% we produced on average 10ˆ5 single photons with a single trapped atom. The non-classical properties of the emitted light has been shown in the photon correlations of just one trapping event.

With a new high-resolution camera system we are now able to monitor the atom within the cavity mode from the side, allowing the simultaneous observation of free-space emission and scattering into the cavity. Finally, we also discuss new insights into the dynamics of the system with single and multiple trapped atoms.

[1] Hijlkema et al, Nature Physics 3, 253-255 (2007).

Q 28.18 Di 16:30 Poster C2

Cooling, storing, and manipulating single atoms in an optical cavity — •Jörg Bochmann, Martin Mücke, David Moehring, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Single atoms coupled to high finesse cavities provide unique systems to study light-matter interactions in the quantum regime. Deterministic generation of single photons and application as a single photon server has been demonstrated [1]. Naturally, these systems are well suited for generation of entangled states between atoms and photons [2].

Efficient operation of these experiments relies on cavity-mediated cooling of the atom within the cavity mode [3]. In our new setup, we reliably trap and cool Rb atoms in a cavity using a 2D-optical lattice of far detuned dipole traps. The cavity parameters put the system at the boundary of the strong coupling regime and we have observed constant coupling of atoms to the cavity over many seconds. Photons generated inside the cavity are outcoupled to an optical fiber and transmitted to a detection setup with ca. 50% efficiency. Improvements regarding a 3D-dipole trap configuration and fast photon generation schemes are in progress.

[1] M. Hijlkema, et al., Nature Physics 3, 253 (2007)
[2] T. Wilk, et al., Science 317, 488 (2007)
[3] S. Nußmann, et al., Nature Physics 1, 122 (2005)

Q 28.19 Di 16:30 Poster C2

Experimental techniques for quantum information processing with trapped $^{40}Ca^+$ ions — •Michael Brownnutt[1], Felicity Splatt[1,2], Max Harlander[1], Wolfgang Hänsel[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Österreich — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Österreich

One of the outstanding requirements for realising quantum computing with trapped ions is the implementation of a truly scalable trap architecture. Proposals for such architectures include segmented linear Paul traps, where the segmentation allows the axial confining potential to be varied. Ions can thereby be independently held in - and moved between - separate trapping regions. We present numerical models of linear shuttling of ions in such traps, and of optimised shuttling through junctions. We also report on developments in fabrication and testing of various segmented trap designs. Finally, work regarding practical aspects of vacuum chamber design will be outlined.

Q 28.20 Di 16:30 Poster C2

Application of optimal control techniques in scalable ion trap quantum logic — •Ulrich Poschinger, Kilian Singer, and Ferdinand Schmidt-Kaler — Institut für Quanteninformationsverarbeitung, Universität Ulm, Albert-Einstein-Allee 11, 89069 Ulm

Strings of laser cooled ions in a Paul trap provide a yet unmatched degree of quantum control[1]. The drawback of this concept lies in the limited scalability, which can be overcome by operating a microstructured array of Paul traps and shuttling the ions between different trap sites. The shuttling operations are carried out by dynamically changing the confining voltages at the trap segments. They have to be fast, robust and should not contribute excess energy to the ion qubit as this would spoil subsequent quantum logic operations. This setting suggests the application of optimal control (OCT) techniques. We present numerical results showing that OCT should indeed make such shuttling operations possible[2]. Furthermore, quantum logic logic gates can benefit from OCT as well since achieving high fidelities is crucial for attaining the quantum error correction threshold[3]. We demonstrate numerically that shaped pulse sequences obtained by OCT allow for the implicit compensation of parameter offsets. Analogously to NMR experiments, the logic operations can therefore be robustified[4].

[1] H.Häffner et al., Nature 438, 643 (2005)
[2] S. Schulz et al., Progress of Physics, Wiley 54, No. 8-10, 648 (2006)
[3] C. Roos, arXiv:0710.1204v3 (2007)
[4] N. Timoney et al. quant-ph/0612106 (2006)

Q 28.21 Di 16:30 Poster C2

HC-PCF based Rubidium vapor cell — •wenjia zhong[1], christoph marquardt[1], ulrik l. andersen[2], and gerd leuchs[1] — [1]Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, 91058 Erlangen, Germany — [2]Department of Physics, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark

Using hollow core photonic crystal fiber as a vapor cell has the advantage of long interaction length and small laser beam area. We filled the core of a HC-PCF with liquid Rubidium using microfluidic methods and put the fiber ends inside vacuum chambers to prevent oxidization and quenching. With a constant temperature along the entire length of the fiber, the rubidium will be evaporated to prevent bulk condensation. The Rb density will be monitored by the help of absorption spectroscopy.

We plan to use the D1 transition of Rb and a femtosecond laser beam to achieve the sharp-line limit of self-induced transparency. The nonlinearity inherent in detuned SIT will then be exploited for the generation of squeezed states.

Q 28.22 Di 16:30 Poster C2

Controlled dynamic generation of entanglement — •Thomas Häberle[1], Kilian Singer[2], and Matthias Freyberger[1] — [1]Institut für Quantenphysik, Universität Ulm, 89069 Ulm — [2]Institut für Quanteninformationsverarbeitung, Universität Ulm, 89069 Ulm

We discuss two compact particles in a harmonic trap which interact via pointlike collisions. The interaction can be modelled by a δ-potential in the relative coordinate of the particles. Each collision will dynamically entangle the particles by a certain amount. Therefore, the time evolution of entanglement will show a step-like behaviour [1]. We now study if it is possible to maximize the entanglement at an arbitrarily fixed time by dynamically varying the trap frequency. We approach this problem by using appropriate techniques [2] from optimal control theory.

[1] M. Bußhardt and M. Freyberger, Phys. Rev. A **75**, 052101 (2007).
[2] T. Calarco et al., Phys. Rev. A **70**, 012306 (2004).

Q 28.23 Di 16:30 Poster C2

Optimiertes Atom-Ion-Quantengatter — •Hauke Doerk-Bendig[1], Zbigniew Idziaszek[2] und Tommaso Calarco[1] — [1]Institut für Quanteninformationsverarbeitung, Universität Ulm, 89079 Ulm, Deutschland — [2]Center for Theoretical Physics, Polish Academy of Science, 02-668 Warschau, Polen

Die gleichzeitige Verwendung von neutralen Atomen und Ionen in der Quanteninformationsverarbeitung ist durch die Kombination der Vorteile beider Spezies motiviert. Einerseits ist die Dekohärenzzeit von Atomen in optischen Gittern lang, andererseits lassen sich Gatteroperationen mit Ionen wegen ihrer relativ starken Wechselwirkung mit hoher Geschwindigkeit durchführen.

Wir wollen die theoretische Grundlage für ein solches Quantengatter schaffen, indem wir die von der inneren Struktur abhängigen Wechselwirkung gefangener Atome mit gefangenen Ionen studieren und mit Hilfe einer durch ein externes Magnetfeld gesteuerten Feshbach-Resonanz kontrollieren.

Unsere weitere Arbeit besteht darin, geeignete Hyperfeinzustände von Atom und Ion für die Kodierung von Qubits zu finden und Fidelity und Laufzeit eines Quantengatters mittels Quantum Optimal Control zu optimieren.

Q 28.24 Di 16:30 Poster C2

Photo-ionization studies of Calcium atoms — •Carsten Schuck, Marc Almendros, Felix Rohde, Francois Dubin, Markus Hennrich, and Jürgen Eschner — ICFO - Institut de Ciencies Fotoniques, 08860 Castelldefels (Barcelona), Spain

We present a novel method for the efficient ionization of neutral Calcium atoms, which is used in our ion trap experiment. The atoms are resonantly excited from the ground state via the intermediate 4s4p $^1P_1$ level close to the continuum, where they are ionized in the strong electric fields of the Paul trap [1]. For the first step a laser source at 423 nm is used while an incoherent source around 390 nm is sufficient for the second step [2]. We use a temperature-stabilized periodically poled $KTiOPO_4$ crystal to create coherent 423 nm light in second harmonic generation from a 170 mW extended cavity diode laser in single pass [3]. A hollow cathode lamp is used to tune the laser to the ^{40}Ca resonance. The 390 nm light is obtained from a high power indium gallium nitride LED, which emits approximately 85 mW of optical output power around its 380 nm peak wavelength. Using achromatic doublet lenses we focus the light from both sources into a multimode fiber and then image the fiber end to a 200 μm spot at the center of the trap, where they are overlapped with the atomic beam.

[1] S. Gulde, et al., Appl. Phys. B **73**, 861 (2001),
[2] D.M. Lucas, et al., Phys. Rev. A **69**, 012711 (2004),
[3] F. Torabi-Goudarzi, E. Riis, Opt. Comm. **227**, 389 (2003).

Q 28.25 Di 16:30 Poster C2

Counterpropagating PDC photon source with PPLN waveguides — •Andreas Christ, Andreas Eckstein, and Christine Silberhorn — Günther-Scharowsky-Str. 1, Bau 24

We investigate the properties of a quasi-phasematched parametric downconversion process in a periodically poled $LiNbO_3$ waveguide. Our aim is to provide a bright source of pure single photon pairs at the telecom wavelength, i.e. 1550 nm. To quantify the amount of frequency entanglement we perform a Schmidt-decomposition of the joint spectrum.

Our focus lies on the creation of counterpropagating photon-pairs and applications in integrated quantum networks:

Firstly these counterpropagating and uncorrelated photons enable us to design a photon source without spatial and spectral filtering. Combined with the application of a waveguide instead of a bulk crystal, we propose an ultrabright source of decorrelated photon pairs.

Secondly we investigate one of the most interesting aspects of counterpropagating photon pairs: The included separation between the signal and idler beams, offering the possibility to separately access the signal and idler photons even for degenerate type-I phasematching.

Q 28.26 Di 16:30 Poster C2

Maple tools for teaching and exploring quantum computation and information protocols — •Thomas Radtke[1] and Stephan Fritzsche[2] — [1]Institut für Physik, Universität Kassel, 34132 Kassel, Germany — [2]Gesellschaft für Schwerionenforschung (GSI), 64291 Darmstadt, Germany

During the last decade, the field of quantum information and computation has been growing rapidly. Beside of the great promise and the potential of various quantum information protocols, such as Shor's factorization algorithm, quantum teleportation and others, however, there are still many open problems to be solved. Although entanglement has been recognized today as a crucial resource for quantum information, it is still not fully understood, especially in the multipartite setting [1].

To assist in the teaching and study of multi-qubit quantum states and algorithms, several software tools have been presented and discussed in the web. More often than not, however, these tools only implement a rather limited set of features or they were focused on special protocols. Therefore, in order to provide a flexible toolbox, we developed the FEYNMAN program within the framework of MAPLE [2]. Apart from a catalogue of frequently used quantum gates and noisy channels this program implements a variety of separability criteria as well as entanglement measures. In this poster, we show how this toolbox can be utilized for teaching basic but also more advanced topics in quantum information theory.

[1] R. Horodecki et al., quant-ph/0702225v2
[2] T. Radtke, S. Fritzsche, Comput. Phys. Commun. 176 (2007) 617