Friday, 22.06.2012, HCI G 3

Time	ID	QSIT I *Chair: Richard Warburton, Uni Basel*
11:00	**801**	**Torque Magnetometry of Individual Ni Nanotubes** *Dennis P. Weber [1], A. Buchter, D. Rüffer, E. Russo-Averchi, A. F. i Morral, D. Grundler, R. Huber, P. Berberich, M. Poggio [1]* *[1] Departement Physik, Universität Basel, Klingelbergstrasse 82, 4056 Basel* Torque Magnetometry serves as a tool to characterize nanometer-scale magnets in an applied magnetic field using the change in the natural frequency of an oscillating force sensor - e.g. an ultrasensitive Si cantilever - as an indicator for the magnitude of magnetization. We study a Ni nanotube, formed by coating a GaAs nanowire template, in various magnetic field configurations. Results suggest different magnetization states within the magnetic nanotube depending on the applied magnetic field direction and strength. These findings are supported by independent magneto-resistance measurements on identical samples. Due to their excellent magnetic properties and small dimensions, such magnetic nanotubes may find application in high resolution magnetic force microscopy (MFM) or magnetic resonance force microscopy (MRFM). The research has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement No. 228673 and the German Excellence Cluster "Nanosystems Initiative Munich".
11:15	**802**	**Characterization of nano-scale electrical contacts using dynamical Coulomb blockade** *Konrad H. Müller [1], Christophe Brun [2], I-Po Hong [3], François Patthey [4], Christian Flindt [1], Wolf-Dieter Schneider [2]* *[1] Département de Physique Théorique, Université de Genève, 24, quai E. Ansermet, 1211 Genève 4* *[2] Inst. des Nanosciences de Paris, Univ. Pierre et Marie Curie 6, 4, place Jussieu, FR-75252 Paris* *[3] Inst. für Experimentelle und Angewandte Physik, C.-A.-Univ. Kiel, Olshausenstr. 40, DE-24098 Kiel* *[4] Institut de Physique de la Matière Condensée, EPFL, Station 3, 1015 Lausanne* The theory of dynamical Coulomb blockade (DCB) has in the past been successful in describing transport measurements in carefully engineered tunnel junctions by explicitly taking into account the electrical circuits in which they are embedded. Here we use the theory of DCB to explain recent scanning tunneling spectroscopy measurements on flat metallic nano-scale islands electrically coupled to their supporting substrates [1]. The observed suppression of the differential tunnel conductance at small bias voltages is due to DCB and can be understood by considering the island--substrate contact as an Ohmic resistor in parallel with a plate capacitor. Our theoretical calculations are in good agreement with the measurements and allow us to investigate the systematic dependence of the resistances and capacitances on the island--substrate contact area. [1] C. Brun, K. H. Müller, I-P. Hong, F. Patthey, C. Flindt, and W.-D. Schneider, Phys. Rev. Lett. (in print)
11:30	**803**	**Scanning gate experiments on graphene nanoribbons** *Nikola Pascher, Dominik Bischoff, Thomas Ihn, Klaus Ensslin* *Solid State Physics Laboratory, ETH Zürich, Schafmattstrasse 16, 8093 Zürich* The metallic tip of a scanning probe microscope operated at 1.7 K is used to locally induce a gating-potential in a graphene nanoribbon. Images of the conductance through the device as a function of tip-position show that two centers of enhanced conductance are formed inside the structure. By applying a linescan-technique, it can be demonstrated, that these two features correspond to two charge localizations, exhibiting the characteristics of quantum dots. Scanning gate microscopy allows to characterize them with high resolution both in real space and energy.

11:45	**804**	**All Electrical Control and Slowing of Microwaves using Circuit Nano-electromechanics** *Xiaoqing Zhou [1], Fredrik Hocke [2], Albert Schliesser [1], Hans Huebl [2], Achim Marx [2], Rudolf Gross [2], Tobias Kippenberg [1]* *[1] EPFL SB ICMP LPQM1, Station 3, 1015 Lausanne* *[2] WMI, Walther-Meißner-Straße 8, DE-85748 Garching* Using a low-mass (~ 15 pg), high-Q (> 100 000) nanomechanical oscillator coupled to a Nb superconducting quarter wave cavity, we realize a circuit nano-electromechanical system coupling microwaves to mechanical motion oscillating at 1.45 MHz. By exciting the system on the lower motional sideband with a strong drive tone, a transparency window for a probe field is created originating from the effect of optomechanically induced transparency (OMIT). This phenomenon, analogous to electromagnetically induced transparency in Atomic Physics, arises from the interference of different excitation pathways for an intracavity probe field. We utilize the transparency window to demonstrate slow microwave propagation. A tunable delay up to 4 ms is demonstrated experimentally for a microwave pulse on resonance with the cavity. Furthermore, we systematically investigate the temporal dynamics of this transparency window when the drive tone is modulated, and the effect of the oscillator's Duffing nonlinearity on the OMIT window.
12:00		***Postersession (continued), Lunchbuffet***
		QSIT II *Chair: Klaus Ensslin, ETH Zürich*
13:30	**811**	**Graphene Quantum Dots** *Johannes Güttinger* *Institut Català de Nanotechnologia (ICN) Campus de la UAB, ES-08193 Bellaterra* We report transport experiments through graphene quantum dots and narrow graphene constrictions. In a quantum dot, electrons are confined in all dimensions, offering the possibility for detailed investigation and controlled manipulation of individual quantum systems. The recently isolated two-dimensional graphene is an interesting new material to study quantum phenomena. Due to its novel electronic properties and the expected weak interaction of the electron spin with the atomic nuclei, graphene quantum dots have been proposed as promising hosts for spin based quantum bits. As graphene is a zero gap semiconductor, tunable carrier confinement poses a challenge. We fabricate graphene quantum dots by etching mono-layer flakes into 60-350 nm sized islands with narrow constrictions to the leads. Transport through the constrictions is suppressed around the electron-hole crossover and they can be used as tunable tunneling barriers for transport spectroscopy of the dot. Electron confinement in graphene quantum dots is observed by measuring Coulomb blockade and transport through excited states, a manifestation of quantum confinement [1]. In order to understand the spectrum of a quantum dot it is usually necessary to reach a regime with only one or two electrons in the dot. Measurements in a magnetic field perpendicular to the sample plane allow identifying the electron-hole transition regime via the crossover to the graphene specific zero-energy Landau level at high fields. After rotation of the sample into parallel magnetic field orientation, Zeeman spin-splitting with a g-factor of approximately two is measured. A g-factor of two is expected in the absence of spin-orbit interaction. The filling sequence of subsequent spin states showed no signatures of shell filling so far. This is attributed to the non negligible influence of exchange interactions among the electrons and low energy edge states [2]. These studies open the way for a more advanced understanding and control of spin states in graphene quantum dots. [1] J. Güttinger, „Graphene Quantum dots" Ph D thesis, ETH Zurich (2011) [2] J. Güttinger, T. Frey, C. Stampfer, T. Ihn, and K. Ensslin, „Spin States in Graphene Quantum Dots" PRL 105, 116801 (2010)
14:00	**812**	**Rectification of thermal fluctuations in a chaotic cavity heat engine** *Björn Sothmann [1], Rafael Sánchez [2], Andrew N. Jordan [3], Markus Büttiker [1]* *[1] Dép. de Physique Théorique, Université de Genève, 24, quai Ernest Ansermet, 1211 Genève* *[2] Instituto de Ciencia de Materiales de Madrid (ICMM-CSIC), c/ Sor Juana Ines de la Cruz 3, ES-28049 Madrid* *[3] Department of Physics and Astronomy, University of Rochester, Rochester, NY 14627-0171, USA* Recently, the influence of fluctuations on transport through quantum dots has generated a lot of interest. In Ref. [1], it was shown how a pair of capacitively-coupled quantum dots in a three-terminal

		device can convert a heat current into a charge current. This converter is optimal in the sense that it transfers one electron for every heat quantum delivered by the hot dot. However, the currents generated are very small. Of interest is the scaling of this effect as the system size increases. Here, we consider a heat engine consisting of a hot chaotic cavity capacitively coupled to a cold cavity which rectifies the excess noise and generates a directed current. The fluctuation-induced directed current depends on the energy asymmetry of the transmissions of the contacts of the cold cavity to the leads and is proportional to the temperature difference. We discuss the maximal power output of the heat engine and its efficiency. [1] R. Sánchez and M. Büttiker, Phys. Rev. B 83, 085428 (2011). [2] B. Sothmann, R. Sánchez, A. N. Jordan, and M. Büttiker, arXiv:1201.2796v1 (2012).
14:15	**813**	**Fiber-cavity spectroscopy of quantum wells and charge-controlled quantum dots** *Javier Miguel-Sanchez [1], Andreas Reinhard [1], Thomas Volz [1], Emre Togan [1], Benjamin Besga [2], Jérôme Estève [2], Jakob Reichel [2], Ataç Imamoglu [1]* *[1] Institute for Quantum Electronics, ETH Zürich, HPT G5, Wolfgang Pauli Strasse 16, 8093 Zürich* *[2] Laboratoire Kastler Brossel, CNRS, École Normale Supérieure, 24 rue Lhomond, FR-75005 Paris* We present a novel experimental platform for the realization of polariton boxes with quantum-well cavity exciton-polaritons. Photonic mode is defined through a concave dielectric DBR mirror at the end of a fiber-tip which is approaching the sample surface from the top. A second DBR is embedded in the semiconductor structure, below the QW. Full tunability of the system is ensured by mounting the sample on nano-positioner stages. The low T experiments show normal mode splitting for a single quantum well sample, the vacuum Rabi splitting amounts to 2g ~ 3.4 meV. We investigate multiple quantum well samples to find signatures of polariton condensation. Additionally, used p-i-n QDs diodes grown on top of a DBR mirror. We show charge control of the QD excitonic states and the characterization of the effective two level system coupled to the cavity.
14:30	**814**	**Supplying cluster states for one-way quantum computing** *Daniel Becker [1], Tetsufumi Tanamoto [2], Vladimir M. Stojanovic [1], Christoph Bruder [1]* *[1] Departement Physik, Universität Basel, Klingelbergstrasse 82, 4056 Basel* *[2] Corporate R & D center, Toshiba Corporation, Saiwai-ku, JP-2128582 Kawasaki* One-way quantum computing allows to perform a quantum computation by a sequence of local qubit measurements applied to certain resource- or cluster states. The common spin Hamiltonians such as the Ising, XY, or Heisenberg model, however, do not have ground states that are the cluster states needed in one-way quantum computing. This makes it difficult to preserve these states in solid-state systems due to their short coherence times. Here we propose a scheme for generating a time evolution governed by an effective Hamiltonian that has a cluster state as ground state. Our approach employs a series of pulses inspired by established NMR techniques and holds promise for applications in many areas of quantum information processing.
14:45	**815**	**Multilevel transport in a three-terminal graphene quantum dot** *Pauline Simonet, Arnhild Jacobsen, Klaus Ensslin, Thomas Ihn* *Solid State Physics Laboratory, ETH Zürich, Schafmattstrasse 16, 8093 Zürich* We present transport measurements in the multi-level transport regime of a three-terminal graphene quantum dot. With three terminals, the transmission properties of each tunnel junction can be determined by measuring the complete conductance matrix of the system. Accurate measurements of individual conductance resonances in the Coulomb blockade regime appear at slightly different resonance energies depending on the pair of leads used for probing. We argue that this is due to different coupling strengths of different single-particle levels in the dot to the three leads. Our data can be qualitatively reproduced within a rate equation model using reasonable system parameters. Consequently, our measurements give qualitative insight into the spatial distribution of the quantum dot wave functions. Our results indicate that they are single wave functions extended over the full dot area rather than several localized states. This is an important insight in view of the potential use of graphene quantum dots for spin qubits.

15:00	**816**	**Quantum Hall effect in Graphene with superconducting electrodes** *Peter Rickhaus, Markus Weiss, Christian Schönenberger* *Departement Physik, Universität Basel, Klingelbergstrasse 82, 4056 Basel* We report on the realization of an integer quantum Hall system with superconducting electrodes. Graphene was contacted to niobium electrodes that show a critical field of about 4 Tesla, where electronic transport passes mainly through quantum Hall edge-states and bulk transport is largely suppressed. We find a magnetic field range of more than one tesla where well developed quantum Hall plateaus coexist with superconductivity in the leads. In high magnetic fields with the electrodes in the normal state we observe plateaus at $G=e^2/h$ for n=2, 4, and 10. Reducing the magnetic field to below the upper critical field of the electrodes, the conductance on the plateaus shows a sudden increase. Whereas the conductance on the n=2 plateau increases only by 10%, the increase on the n=6 and n=10 plateau is considerably larger with 60% and 80%, respectively. We attribute this conductance enhancement to multiple Andreev reflection processes along the graphene-superconductor interface, that lead to the formation of Andreev edge-states. The observed conductance enhancement of the n=6 and 10 plateaus is consistent with a doubling of the conductance contribution of the second and third edge-states. We attribute the small conductance increase on the n=2 plateau to the special nature of the zero energy Landau level, that makes the corresponding edge-state sensitive to the structure of the graphene edge.
15:15	**817**	**Quantum Metrology with a Scanning Probe Atom Interferometer** *Caspar Ockeloen, Roman Schmied, Philipp Treutlein* *Department Physik, Universität Basel, Klingelbergstrasse 82, 4056 Basel* We experimentally realize a Ramsey interferometer operating beyond the standard quantum limit (SQL), using two spin states of a two-component Bose-Einstein condensate. We first produce spin-squeezed states by controlled collisional interactions between the atoms using a state-dependent microwave near-field potential. We observe spin noise reduction by up to 4.5dB below the SQL with a spin coherence of 98%. Using such spin-squeezed states as interferometer input states, we demonstrate performance beyond the SQL. Our interferometer outperforms an ideal classical interferometer with the same number of particles (1300) for interrogation times up to 20 ms. These experiments are performed on a micro-fabricated atom chip providing small and well-localized trapped atomic ensembles, allowing for high-precision measurements with micrometer spatial resolution. As a demonstration, we measure level shifts due to an on-chip microwave field, and demonstrate the ability to scan the interferometer position close to the chip surface.
15:30		***Coffee Break***
		QSIT III *Chair: Matthias Christandl, ETH Zürich*
16:00	**821**	**Dark state spectroscopy of a single hole spin** *Julien Houel, Jonathan Prechtel, Andreas Kuhlmann, Richard J. Warburton* *Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel* A hole spin in a quantum dot is potentially coherent on account of the strong confinement and the strong suppression of its contact hyperfine interaction. One method to explore hole spin coherence is with an optical experiment, charge population trapping (CPT), equivalently dark state spectroscopy. For weak optical couplings, we show that the hole spin is coherent enough for us to measure a CPT dip as narrow as 13 MHz (50 neV) bringing semiconductor spectroscopy into the realm of atomic physics. However, the dip position is not the same from run to run. We propose that these fluctuations are caused by low frequency electrical noise which results in spin noise via the electric field-dependence of the hole g-factor. Our results imply that presently, the main challenge in engineering a coherent hole spin is to reduce the charge noise.
16:30	**822**	**Exploring cavity-mediated long-range interactions in a dilute quantum gas** *Renate Landig, Rafael Mottl, Kristian Baumann, Ferdinand Brennecke, Tobias Donner,* *Tilman Esslinger, Institute for Quantum Electronics, ETH Zürich, Schafmattstrasse 16, 8093 Zürich* We create a Bose-Einstein condensate with long-range atom-atom interactions which are mediated by the vacuum field of an optical cavity. These long-range interactions lead to a phase transition (equivalent to the Dicke quantum phase transition) between a normal and a supersolid phase, where

		the atoms arrange on a checkerboard lattice. We report on the observation of a characteristic change in the excitation spectrum reminiscent of a roton minimum and increased density fluctuations due to the long-range interactions. The openness of the cavity allows for time-resolved information about the density fluctuations.
16:45	**823**	**Density functional theory for static and dynamic properties of atomic quantum gases** *Ilia Zintchenko [1], Lei Wang [1], Sebastiano Pilati [2], Ping Nang Ma [1], Matthias Troyer [1]* *[1] Institute for Theoretical Physics, ETH Zürich, Wolfgang-Pauli-Str. 27, 8093 Zürich* *[2] The Abdus Salam International Centre for Theoretical Physics, Strada Costiera 11, IT-34014 Trieste* Since the landmark work of Hohenberg and Kohn in 1965, density functional theory has been widely used in ab initio simulations in solids state, materials and bio physics. With a novel energy functional for ultracold repulsive fermionic atoms derived from fixed-node diffusion Monte Carlo calculations of homogeneous systems we can use the extensive tool-set developed for materials also for atomic gases. We study ferromagnetism in harmonic traps and shallow optical lattices and simulate collision dynamics of atomic clouds. These applications allow us to explore limitations of DFT functionals across ferromagnetic phase transitions and to potentially improve simulation methods for materials.
17:00	**824**	**Quantum state tomography of 1000 bosons: reduced density matrices** *Michael Walter [1], Matthias Christandl [1], Roman Schmied [2], Philipp Treutlein [2]* *[1] Institut für Theoretische Physik, ETH Zürich, Wolfgang-Pauli-Str. 27, 8093 Zürich* *[2] Departement Physik, Universität Basel, Klingelbergstrasse 82, 4056 Basel* We report on joint work on quantum state tomography for systems of many indistinguishable bosonic qubits. Oftentimes, large numbers of particles prohibit the complete reconstruction of the full density matrix. However, many important features are already captured by the reduced density matrices or, equivalently, by the highest-order (i.e., longest-wavelength) terms of the Wigner function. We describe a filtered backprojection algorithm for reconstructing the Wigner function, which is numerically stable and insensitive to fluctuations and noise. By combining it with a semidefinite program, we find the closest physical reduced density matrix matching the experimental data. We demonstrate our method by doing tomography for a squeezed Bose-Einstein condensate.
17:15	**825**	**Ultrastrong Coupling of the Cyclotron Transition of a 2D Electron Gas to a THz Metamaterial** *Curdin Maissen [1], Giacomo Scalari [1], Dana Turcinkova [1], David Hagenmüller [2], Simone De Liberato [2], Cristiano Ciuti [2], Christian Reichl [3], Werner Wegscheider [3], Dieter Schuh [4], Mattias Beck [1], Jérôme Faist [1]* *[1] Institut für Quantenelektronik, ETH Zürich, Wolfgang-Pauli-Str. 16, 8093 Zürich* *[2] Laboratoire Matériaux et Phénomènes Quantiques, Université Paris Diderot-Paris 7, 10, rue Alice Domon et Léonie Duquet, FR-75013 Paris* *[3] Institut für Festkörperphysik, ETH Zürich, Schafmattstrasse 16, 8093 Zürich* *[4] Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstraße 31, DE-93053 Regensburg* Artificial cavity photon resonators with ultrastrong light-matter interactions are attracting interest both in semiconductor and superconducting systems because of the possibility of manipulating the cavity quantum electrodynamic ground state with controllable physical properties. We report here experiments showing ultrastrong light-matter coupling in a terahertz (THz) metamaterial where the cyclotron transition of a high-mobility two-dimensional electron gas (2DEG) is coupled to the photonic modes of an array of electronic split-ring resonators. We observe a normalized coupling ratio, $\Omega/\omega_c = 0.58$, between the vacuum Rabi frequency, Ω, and the cyclotron frequency, ω_c. Our system appears to be scalable in frequency and could be brought to the microwave spectral range with the potential of strongly controlling the magnetotransport properties of a high-mobility 2DEG.
17:30		***END***

ID	QSIT POSTER
841	**Electronic transport in ultra-clean carbon nanotube quantum dots** *Stefan Nau, Markus Weiss, Christian Schönenberger* *Departement Physik, Universität Basel, Klingelbergstrasse 82, 4056 Basel* Ultra-clean carbon nanotube (CNT) devices have been shown to have extraordinary electronic and mechanical properties. We present nonlinear conductance measurements on such a device contacted to platinum electrodes. The very clean transport characteristics enable us to observe inelastic cotunneling, accompanied by negative differential conductance. We attribute this to the coupling of tunneling electrons to the vibrational modes of a suspended part of the CNT. Coupling such a device to superconducting electrodes would allow the observation of new physics, coming from the interplay of mechanical vibrations, curvature induced spin orbit coupling, and proximity induced superconductivity on the CNT. The challenge here is to find materials that are suitable for contacting a CNT while at the same time their superconducting properties are not affected by the high temperature CVD growth process. We present first results of transport data that show signs of superconductivity in nonlinear transport.
842	**Quantum dots in the quantum Hall regime** *Stephan Baer, Clemens Rössler, Thomas Ihn, Klaus Ensslin, Christian Reichl, Werner Wegscheider* *Solid State Physics Laboratory, ETH Zürich, Schafmattstrasse 16, 8093 Zürich* Quantum dots in strong perpendicular magnetic fields are an interesting system to investigate (fractional) quantum Hall physics. We present measurements of a large quantum dot, fabricated on a high-mobility 2DEG. Magnetoresistance oscillations, measured as a function of magnetic field and gate voltages in the quantum Hall regime, arise from a Coulomb blockade mechanism. Different coupling strengths of edge states inside the dot can directly be extracted, both from direct transport, as well as from measurements using charge detection techniques. This gives spatial information about the formation of edge channels in the quantum dot.
843	**Progress toward nanoscale magnetic resonance with a "magnet-on-cantilever" force microscope** *Phani Peddibhotla, Fei Xue, Martino Poggio, University of Basel, Klingelbergstrasse 82, 4056 Basel* The magnetic resonance force microscope (MRFM) consists of a cantilever sensor which can detect the force experienced by the spins in a sample. There are two variants in the geometry of MRFM – sample-on-cantilever and magnet-on-cantilever. The recent progress in MRFM has largely been confined to the sample-on-cantilever geometry resulting in the spin detection sensitivities and spatial resolution achievable on the order of 10^3 spins and 10 nm respectively. The magnet-on-cantilever geometry would give us more flexibility in studying samples such as molecules on surfaces and sub-surface spins in QWs and QDs. We will explain the efforts we have put in the magnet-on-cantilever setup to push the limits of spin detection. The ferromagnetic Ni nanowires intended for use as sources of magnetic field gradient are glued to the tip of the cantilever using a micromanipulator setup. The sample under study is hydrogen spins in polystyrene lying on a substrate.
844	**Tunnel barriers for spin injection into graphene** *Matthias Bräuninger, Romain Maurand, Christian Schönenberger* *Departement Physik, Universität Basel, Klingelbergstrasse 82, 4056 Basel* Due to weak hyperfine interactions and spin-orbit coupling, graphene promises long spin relaxation times. Recent experiments show that these can be as high as 6 ns in bilayer and 1 ns in single-layer graphene. In order to achieve successful spin injection from ferromagnets into graphene, tunnel barriers are required which conserve the spin polarisation across the interface. We are working towards spin injection from permalloy electrodes through tunnel barriers made of ALD-grown aluminium oxide and electron beam-evaporated MgO. We will present details of tunnel barrier fabrication and first results of successful spin injection into single-layer graphene.
845	~~**A hybrid on-chip opto-nanomechanical transducer for ultra-sensitive force measurements**~~ ~~*Emanuel Gavartin, Pierre Verlot, Tobias J. Kippenberg*~~ ~~*Institute of Condensed Matter Physics, EPFL, SB-ICMP-LPQM1, Station 3, 1015 Lausanne*~~ ~~Nanomechanical oscillators have been employed as transducers to measure force, mass and charge with high sensitivity. Here, we report the realization and operation of a hybrid monolithically integrated transducer system consisting of a high-Q nanomechanical oscillator with modes in the MHz regime coupled to the near-field~~

~~of a high-Q optical whispering-gallery-mode microresonator. The transducer system has a force sensitivity of 74 aN Hz$^{-1/2}$ at room temperature. Energy averaging, required to retrieve incoherent signals, converges only very slowly with the fourth root of the averaging time. We propose and explicitly demonstrate by detecting a weak incoherent force that this constraint can be significantly relaxed by use of dissipative feedback. We achieve a more than 30-fold reduction in averaging time with our hybrid transducer and are able to detect an incoherent force being 25 times smaller than the thermal noise and would otherwise remain out of reach.~~ *cancelled*

846 **Probing charge noise in a semiconductor with laser spectroscopy on a single quantum dot**

Andreas Kuhlmann, Julien Houel, Fei Xue, Martino Poggio, Arne Ludwig, Richard Warburton
Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel

We probe noise using high resolution optical spectroscopy on a single self-assembled quantum dot (QD). We demonstrate that the QD is sensitive to changes in the local environment at the single charge level through large energy shifts of the QD absorption. By controlling the charge state of localized defects, we are able to create a map of the defects with 5 nm resolution. Fluctuating charges further away from the dot are detected by small changes to the QD signal. We present the characteristic frequency dependence of the charge noise, the ability to suppress the noise with feedback schemes, and we discus the influence of charge noise on the absorption linewidth of the QD.

847 *cancelled*

848 **Cold collisions in an ion - atom hybrid trap**

Felix Hall [1], Pascal Eberle [1], Mireille Aymar [2], Nadia Bouloufa-Maafa [2], Olivier Dulieu [2], Stefan Willitsch [1]
[1] Department of Chemistry, University of Basel, Klingelbergstrasse 80, 4056 Basel
[2] Laboratoire Aimé Cotton, CNRS, Université Paris-Sud XI, Bâtiment 505, FR-91405 Orsay

We present a combined experimental and theoretical study of cold collisions between laser cooled Ca^+ ions and Rb atoms in an ion-atom hybrid trap. We observe a rich variety of collisional processes consisting of an interplay between non-adiabatic and radiative charge exchange as well as radiative molecule formation, which are interpreted using high-level electronic structure calculations. We study the role of light-assisted processes and show that the efficiency of the dominant inelastic pathways is considerably enhanced in excited channels [1]. We investigate the average collision energy dependence of the observed processes in the range 20 mK $\leq \langle E_{coll}/k_B \rangle \leq$ 20 K, the lowest energies being achieved with studies of just a single ion. Our results point to a general framework of radiative and nonradiative processes dominating the cold reactive collisions in ion-atom hybrid traps.

[1] F. H. J. Hall et al; Phys. Rev. Lett. 107, 243202 (2011)

849 **Design and development of a surface electrode ion trap for sympathetically cooled molecular ions**

Arezoo Mokhberi, Stefan Willitsch, Department of Chemistry, University of Basel, Klingelbergstr. 80, 4056 Basel

Quantum state-controlled molecular ions cooled sympathetically by the interaction with laser-cooled atomic ions are of great interest for new applications in quantum information science, precision spectroscopy and collision studies [1-3]. Surface electrode radio frequency ion traps represent a new type of trapping architecture in which all electrodes lie in a plane and the ions are trapped above the surface [4]. These types of traps offer a high flexibility for manipulating, separating, and shuttling of cold ions, which is relevant for, e. g., large-scale quantum information processing [4] and quantum optics experiments with trapped molecules [3]. We have developed a six-wire surface electrode trap [5] for the sympathetic cooling and coherent manipulation of molecular ions [6]. We present a detailed discussion of the design, a theoretical characterization of the trap properties and first experimental results.

[1] S. Willitsch, Int. Rev. Phys. Chem., to be published.
[2] J. Mur-Petit, et al., Phys. Rev. A 85, 022308 (2012)
[3] D. I. Schuster, et al., Phys. Rev. A 83, 012311 (2011)
[4] J. Chiaverini, et al., Quantum Inf. Comput., 2005, 5, 419
[5] Allcock, D. T. C., et al., New Journal of Physics, 12 (5), 053026.
[6] I. M. Georgescu, S. Willitsch, Phys. Chem. Chem. Phys,13 (2011),18852.

850	**Density Matrix Renormalization Group for Optical Lattices** *Michele Dolfi [1], Bela Bauer [2], Matthias Troyer [1]* *[1] Theoretische Physik, ETH Zürich, Wolfgang-Pauli-Str. 27, 8093 Zürich* *[2] Microsoft Research, Station Q, University of California, CNSI Bldg., Office 2243, 93106 Santa Barbara, USA* The widely used density matrix renormalization group (DRMG) method often fails to converge in systems with multiple length scales, such as lattice discretization of continuum optical lattices. The local optimizations employed by DMRG to optimize the wave function are ineffective in updating large scale features. Here we present a multigrid algorithm that solves these convergence problems by optimizing the wave function at different spatial resolutions. We demonstrate its effectiveness by simulating bosons and fermions in continuous space with an external optical lattice potential. We study non-adiabaticities when ramping up the strength of the external potential, and we suggest new ramping profiles to be employed in cold atoms experiments. The algorithm can be generalized to tensor network methods, and be combined with the contractor renormalization group (CORE) method to study dilute and weakly doped lattice models.
851	**In search of operational quantities for characterizing large quantum systems** *Normand Beaudry, Pascal Basler, Renato Renner* *Institute for Theoretical Physics, ETH Zürich, Wolfgang-Pauli-Str. 27, 8093 Zürich* It is typically difficult to analyze large physical systems directly via their low-energy eigenstates. As a result, much interest has been placed in determining the scaling of the correlations and entanglement in these syste-However, this often relies on information-theoretic quantities whose operational relevance in physics is unclear. Here we propose to quantify the scaling of correlations in large systems using non-asymptotic entropy measures, which have a general operational significance. To demonstrate the feasibility of this approach, we apply it to some simple example systems.
852	**On the Optimality of Work Extraction in Small Thermodynamical Systems** *Philippe Faist, Johan Aberg, Renato Renner* *Institute for Theoretical Physics, ETH Zürich, Wolfgang-Pauli-Str 27, 8093 Zürich* We characterize the work cost of state transitions using a framework based on Landauer's Principle and on the so-called noisy operations introduced by [Horodecki et al, PRA, 2003]. Noisy operations correspond to adding a fully mixed ancilla, performing a unitary, and removing the ancilla. Previous work has demonstrated the relation between these operations and the mathematical notion of majorization. Using Landauer's Principle, we reduce the characterization of work cost or extraction to the consideration of absorbtion or generation during noisy operations of randomness stored in ancillas, similar to the notion of thermomajorization introduced by Horodecki et al. [arXiv:1111.3834v1]. This framework provides a suitable tool to find a lower bound to the work cost of the erasure of a system possessing quantum correlations with a memory, expressed as the min-entropy of the system conditioned on the memory. This bound is complementary to the upper bound presented in [del Rio et al., Nature, 2011].
853	**Ultra-high mobility 2DEGs to observe the 5/2-state** *Christian Reichl [1], Thomas Feil [1], Benedikt Frieß [2], Jürgen Smet [2], Werner Wegscheider [1]* *[1] Solid State Physics Laboratory, ETH Zürich, Schafmattstrasse 16, 8093 Zürich* *[2] Max-Planck-Institut für Festkörperforschug, Heisenbergstrasse 1, 70569 Stuttgart* Two-dimensional electron gases (2DEGs) with $Al_xGa_{x-1}As$ heterostructures with ultra-high mobilities exceeding 10^7 cm^2/Vs are of great interest for several research topics in solid states physics and related fields. The prominent fractional quantized Hall state at $v = 5/2$ features several interesting properties and it requires samples of extremely high quality with minimized crystal and potential disorder. We will present the elaborate growth techniques required to obtain such sample qualities. In collaboration with the MPI Stuttgart, pronounced minima of the length resistance reaching zero were found at magnetic fields that correspond to the 5/2 fractional quantized Hall state. Beyond that, extended Hall plateaus and rentrance states were found in the Hall resistance.