Quantum Science and Technology

This session has been organised in collaboration with the NCCR QSIT.

Tuesday, 27.08.2019, Room G 60

Time	ID	**Quantum Science and Technology I** *Chair: Clemens Müller, IBM Rüschlikon*
14:00	**501**	**Introduction to QSIT Session** *Klaus Ensslin, ETH Zürich*
14:15	**502**	**Scaling elements for ion trap quantum processors** *Jonathan Home [1], Christopher Axline, Tanja Behrle, Chiara Decaroli, Francesco Lancelotti, Thomas Lutz, Maciej Malinowski, Matteo Marinelli, Roland Matt, Brennan Mcneeve, Karan Mehta, Vlad Negnevitsky, Than-Long Nguyen, Robin Oswald, Simon Ragg, Chi Zhang* *[1] ETH Zürich* A useful quantum computer will require quantum-error-correction, which implies a huge increase in resources over systems in laboratories today. In this context, I will describe work towards scaling up trapped-ion quantum computing, including the use of integrated optics, ion shuttling, and attempts to meet the challenges of calibrating and stabilizing larger scale devices. These core elements should facilitate the exploration of error-correcting codes.
14:45	**503**	**Linking trapped-ion quantum nodes** *Tracy Northup, Universität Innsbruck* Future quantum networks offer a route to quantum-secure communication, distributed quantum computing, and quantum-enhanced sensing. The applications of a given network will depend on the capabilities available at its nodes, which may be as simple as quantum-state generation and measurement or as advanced as universal quantum computing. Here, we focus on quantum nodes based on trapped ions, an experimental platform with which high-fidelity state preparation, gate operations, and readout have been demonstrated. By coupling trapped ions to the mode of an optical resonator, we construct a coherent interface between single ions and single photons. I will present ongoing work to transfer quantum states between remote trapped-ion systems, highlighting experimental challenges and addressing the question of how to optimize this process.
15:15	**504**	**Digital Quantum Simulation, Trotter Errors, and Quantum Chaos of the Kicked Top** *Lukas Sieberer [1], Tobias Olsacher [1], Andreas Elben [1], Markus Heyl [2], Philipp Hauke [3], Fritz Haake [4], Peter Zoller [1]* *[1] University of Innsbruck, [2] MPIPKS Dresden,* *[3] Heidelberg University, [4] University of Duisburg-Essen* Quantum simulation enables studying the dynamics of quantum many-body systems in regimes which are inaccessible to numerical methods. With universal digital quantum simulators, time evolution generated by a large class of Hamiltonians can be simulated by approximating the unitary time-evolution operator by a sequence of quantum gates. However, this “Trotterization” introduces an intrinsic source of errors. Our work connects Trotter errors in digital quantum simulation of collective spin systems to quantum chaos of the kicked top: Trotter errors remain bounded in the regime of small Trotter steps, which corresponds to regular motion of the kicked top. Instead, quantum chaos, which sets in above a sharp threshold value of the Trotter step size, leads to the proliferation of Trotter errors.
	~~505~~	*cancelled*

15:30	**508**	**Entanglement transfer using local operations** *Antoine Neven, David Gunn, Martin Hebenstreit, Barbara Kraus, Universität Innsbruck* In quantum systems composed of at least two subsystems, entanglement induces correlations between the properties of the subsystems that cannot be reproduced in classical physics. These strong correlations are used as a resource for many innovative applications of Quantum Physics, such as quantum computation and quantum communication. One operationally meaningful way to characterise this resource is to study the transformations of entangled states that can be achieved using Local Operations assisted with Classical Communication (LOCC). Although it is known that an entangled state can rarely be converted into another one using only LOCC, we show in this talk that combining the resource of several entangled states allows to achieve more local transformations of entangled states.
15:45	**506**	**Experimental secure quantum computing with only classical clients** *Michal Vyvlecka [1], Atul Mantri [2], Giulia Rubino [1], Marco Marcozzi [3], Joseph F. Fitzsimons [2], Philip Walther [1]* *[1] Vienna Centre for Quantum Science and Technology, Faculty of Physics, University of Vienna* *[2] Singapore University of Technology and Design; Centre for Quantum Technologies, National University of Singapore* *[3] School of Science and Technology, Physics Division, University of Camerino* Quantum computers allow for a higher level of security in information exchange than their classical counterpart. As an example, by using the so-called blind quantum computing protocols, a client can delegate a complex quantum computation to a server in a completely secure way, without any leaks of information on the input, the output or the computation algorithm. In this work, we realize a blind quantum computing between a completely classical client and a single quantum server, where the classical client uses an ambiguity in the information flow in measurement-based quantum computing to hide the computation algorithm. Our demonstration represents a step toward real-life applications of blind quantum computing, where classical clients delegate computation tasks to a single photonic quantum server.
16:00	**507**	**Quantum Communication: From Random Numbers To Teleportation** *Rob Thew, Uni Genève* Quantum communication is one of the most advanced areas of quantum science and technology. It spans commercial devices and systems already deployed to future concepts of a quantum internet. We introduce some of the underlying concepts and targeted applications in this rapidly expanding and advancing field. We start with the simple concept of quantum random number generation and their distribution for cryptographic applications. We then discuss next-generation schemes for the distribution of entanglement, teleportation, and the development of complex communication networks.
16:30		***Coffee Break***
		Quantum Science and Technology II *Chair: Shabir Barzanjeh, IST Austria*
17:00	**511**	**A Broadband Rb Vapor Cell Quantum Memory for Single Photons** *Gianni Buser [1], Roberto Mottola [1], Janik Wolters [1], Chris Müller [2], Tim Kroh [2], Liang Zhai [1], Richard Warburton [1], Oliver Benson [2], Philipp Treutlein [1]* *[1] Universität Basel, [2] Humboldt-Universität zu Berlin* Quantum memories are an essential ingredient for quantum repeaters. Further, through synchronization they can facilitate the generation of multiphoton states. This enables scaling optical quantum information processing experiments into a regime beyond the realm of classical simulation. We implemented a broadband optical quantum memory with on-demand storage and retrieval in hot Rb vapor. Operating on the Rb D_1 line, this memory is suited for storing single photons emitted by GaAs droplet quantum dots or by spontaneous parametric down conversion (SPDC) sources. We demonstrate storage of true single photons with a bandwidth of 200 MHz, generated by a SPDC source with 50% heralding efficiency, and show non-classical $g^{(2)} < 1$ of the photons read out of the memory.

17:15 **512**

Sub-second optical storage using dynamical decoupling in an atomic frequency comb memory

Adrian Holzäpfel, Jean Etesse, Krzysztof T. Kaczmarek, Alexey Tiranov, Nicolas Gisin, Mikael Afzelius, University of Geneva

Quantum memories are key devices for future quantum networks. The atomic frequency comb (AFC) scheme in rare-earth doped crystals provides solid-state memories with many appealing features, such as high efficiency, multimode capacity and long storage times. The previous record storage time achieved in an AFC memory was around 1 ms, in a Europium-doped Y_2SiO_5 crystal at zero applied magnetic field. Even longer storage should be possible by dynamical decoupling (DD) of the spin states, but efficient DD was so far unsuccessful at zero field due to the double degenerate nuclear states. In our newest work we demonstrate storage of optical pulses for up to half a second using the AFC scheme and DD in a Eu:Y_2SiO_5 crystal under magnetic field.

17:30 **513**

Ultra coherent nanomechanical oscillators

Tobias Kippenberg, Sergey Fedorov, Nils Johan Engelsen, Amir Ghadimi, Mohammadjafar Bereyhi, Alberto Beccari, EPFL

Mechanical oscillators have a rich history and role in precision science, ranging from the atomic force microscope, gravitational wave detection to technology such as filters in cell phone or quartz oscillators. The dissipation of the mechanical oscillator plays a key role in setting the thermal decoherence rate, limiting e.g. the ability to observe radiation pressure quantum effects, or placing a limit on force sensitivity. In recent years advances in material strain engineering, phononic band-structure engineering and nanofabrication have allow to create mechanical oscillators with unprecedented coherence. In this talk these advances are reviewed which enable mechanical oscillators with room temperature quality factors as high as 1 billion, sufficient for room temperature ground state cooling of a macroscopic mechanical oscillator.

18:00 **514**

Quantum Simulation with Ultracold Dipolar Atoms

Francesca Ferlaino
Institute for Experimental Physics, University of Innsbruck and IQOQI Innsbruck

Quantum simulations open the path for understanding complex quantum matter. Among the large variety of possible approaches, ultracold quantum gases offer a skilful realization of models in condensed matter physics from the weakly to the strongly correlated regime. The key benefits lie on in the ability to reach a high degree of isolation and state control, to change the system's dimensionality, and to engineer the interaction between particles. So far, the large majority of realized systems employed ultracold atomic species with dominant contact interactions. However, recently highly magnetic species established themselves as novel powerful resources in the quantum realm thanks to their long-range and anisotropic dipole-dipole interaction.

Today, the quest for dipolar quantum simulators marks one of the latest developments in the rapidly evolving field of quantum gases. This talk will present an overview of our latest developments, from the first realizations of quantum-degenerate dipolar gases and mixtures of erbium and dysprosium, to the observation of novel quantum-fluid phenomena such as roton excitation and supersolid phases and the realization of strongly correlated many-body quantum systems of increased complexity. For magnetic atoms confined in light crystals, we will show how the large spin nature of our magnetic atoms and the long-range character the interaction remove the restriction of on-site interaction and allow to process extended Hubbard-type Hamiltonians with extra spin degrees of freedom.

18:30 **515**

Scattering from the dark and birefringent modes: new self-organisation phases

Davide Dreon, Philip Zupancic, Alexander Baumgärtner, Xiangliang Li, Andrea Morales, Tobias Donner, Tilman Esslinger, ETH Zürich

A Bose-Einstein Condensate (BEC) inside an optical resonator can undergo a phase transition to a self-organised state when illuminated with a red-detuned pump beam.

In our recent experiment, we explore the blue-detuned case. We observe that self-organisation is still possible despite the atoms being expelled from the light fields. Moreover, the repulsive lattice modifies the inter-band coupling and the dispersive shift triggers dynamics of the order parameter, both effects leading to richer phase diagrams.

		In a second experiment, we study the interaction of the BEC with two non-degenerate polarisation modes of a cavity. I will show how the couplings to the modes - independently tuned via the scalar and vector atomic polarisability - give rise to competing self-organisation phases.
18:45	**516**	**Local spin manipulation of quantized atomic currents** *Laura Corman, Martin Lebrat, Samuel Häusler, Philipp Fabritius, Dominik Husmann, Tilman Esslinger, ETH Zürich* Controlling the internal state of a particle in an ultracold atom experiment is important for studying spinor phases and to simulate spin physics. This control can be implemented using light fields that couples differently to the internal states. This was successfully used in several experiments, although the experiment time is usually constrained by the heating induced by the laser beams. Here, we create fully spin-polarized currents in an ultracold experiment of fermionic lithium. By shining the spin-dependent, close-to-resonant beam on a small constriction connecting two reservoirs, we demonstrate that the heating is limited: we lift the spin degeneracy for weak interactions while retaining conductance plateaus. This setup can be use to detect small variations of transport thanks to interactions.
19:00		
19:30		***Public Lecture***

Wednesday, 28.08.2019, Room G 60

Time	ID	QUANTUM SCIENCE AND TECHNOLOGY III *Chair: Matthias Mergenthaler, IBM Rüschlikon*
14:00	**521**	**Quantum Information Science with Superconducting Circuits** *Andreas Wallraff, Department of Physics, ETH Zürich* Superconducting circuits are a prime contender for realizing universal quantum computation in fault-tolerant processors and for solving noisy intermediate-scale quantum (NISQ) problems with non-error-corrected ones. Superconducting circuits also play an important role in state of the art quantum optics experiments and provide interfaces in hybrid systems when combined with semiconductor quantum dots, color centers or mechanical oscillators. In this talk, I will introduce the operation of superconducting circuits in the quantum regime and put quantum information processing with superconducting circuits into perspective with other solid state and atomic physics approaches. As one of two examples of our own research work in the area of fault tolerant quantum computing, which relies on the ability to detect and correct errors, I will present an experiment in which we stabilize the entanglement of a pair of superconducting qubits using parity detection and real-time feedback [1]. In quantum-error-correction codes, measuring multi-qubit parity operators projectively and subsequently conditioning operations on the observed error syndrome is quintessential. We perform experiments in a multiplexed device architecture [2], which enables fast, high-fidelity, single-shot qubit read-out [3], unconditional reset [4], and high fidelity single and two-qubit gates. As a second example, I will present the realization of a deterministic state transfer and entanglement generation protocol aimed at extending monolithic chip-based architectures for quantum information processing. Our all-microwave protocol exchanges time-symmetric itinerant single photons between individually packaged chips connected by transmission lines to achieve on demand state transfer and remote entanglement fidelities of about 80 % at rates of 50 kHz [5]. We believe that sharing information coherently between physically separated chips in a network of quantum computing modules is essential for realizing a viable extensible quantum information processing system. [1] C. Kraglund Andersen et al., arXiv:1902.06946 (2019) [2] T. Walter et al., Phys. Rev. Applied 7, 054020 (2017) [3] P. Magnard et al., Phys. Rev. Lett. 121, 060502 (2018) [4] J. Heinsoo et al., Phys. Rev. Applied 10, 034040 (2018) [5] P. Kurpiers et al., Nature 558, 264-267 (2018)

14:30 | **522**

Gate-efficient simulation of molecular eigenstates on a quantum computer

Marc Ganzhorn [1], Daniel Egger [1], Panagiotis Barkoutsos [1], Pauline Ollitrault [1], Gian Salis [1], Nikolaj Moll [1], Andreas Fuhrer [1], Marco Roth [2], Peter Müller [1], Ivano Tavernelli [1], Stefan Woerner [1], Stefan Filipp [1]
[1] IBM Research, [2] RWTH Aachen & FZ Jülich

In order to perform simulations of quantum systems on current quantum processors, quantum algorithms with short circuit depth have to be designed. Here, we experimentally demonstrate that exchange-type gates, tunable in amplitude and phase, are ideally suited for calculations in quantum chemistry [1]. We optimize and characterize these exchange-type gates, which yield an average gate fidelity of 95% obtained via randomized benchmarking. Finally, we determine the energy eigenstates of molecular hydrogen with an accuracy of 50 mHa using a variational quantum eigensolver algorithm based on exchange-type gates in combination with a method from computational chemistry to compute the excited states.

[1] M. Ganzhorn et al., Phys. Rev. Applied 11, 044092

14:45 | **523**

Interacting TLS as sources of noise and fluctuations in superconducting circuits

Clemens Müller [1], Steffen Schlör [2], Jürgen Lisenfeld [2], Alexander Shnirman [2], Martin Weides [3], Matthias Mergenthaler [1], Andreas Fuhrer [1]
[1] IBM Research Zurich, [2] Karlsruhe Institute of Technology, [3] University of Glasgow

Since the very first experiments, superconducting circuits are suffering from coupling to environmental noise, destroying quantum coherence and degrading performance. In state-of-the-art experiments, it is found that the relaxation time of superconducting qubits fluctuates as a function of time. We present measurements of such fluctuations in 2D and 3D-transmon circuits and develop a qualitative model based on interactions within a bath of background two-level systems (TLS) which emerge from defects in the device material. In our model, the time-dependent noise density acting on the qubit emerges from its near-resonant coupling to high-frequency TLS which experience energy fluctuations due to their interaction with thermally fluctuating TLS at low frequencies.

15:00 | **524**

Transduction and entanglement generation with silicon nanobeam oscillators

Johannes Fink, Institute of Science and Technology Austria

We will present recent experimental progress with micro-machined silicon nanomechanical systems. The interplay between parametric driving, interference and dissipation in a multi-mode cavity electro-optomechanical system can either be used to break time reversal symmetry and act as a compact on-chip microwave circulator [1], to realize bidirectional microwave to telecom conversion, or to deterministically entangle intinerant microwave modes [2]. Observation of such stationary entanglement not only reveals the quantum nature of the mechanical oscillator without measuring it directly, it also represents an important resource for quantum communication and quantum enhanced detection.

[1] Mechanical On-Chip Microwave Circulator. S. Barzanjeh, et al., Nature Commun. 9, 953 (2017)
[2] Stationary Entangled Radiation from Micromechanical Motion. S. Barzanjeh, et al. Nature, in print (2019)

15:30 | **525**

Experimental Realization of Microwave Quantum Illumination

Shabir Barzanjeh, Johannes Fink, Institute of Science and Technology Austria

Quantum illumination is a quantum sensing technique in which quantum correlation is used to improve the detection of a low-reflectivity object that is immersed in a bright thermal background. Here, using a superconducting circuit platform we experimentally implement quantum illumination at microwave frequencies. We use a Josephson parametric converter to generate stationary entanglement between microwave radiation and use the correlated photons to probe the region to detect the existence or absence of a target. We show that the signal-to-noise ratio of the microwave quantum-illumination system is superior to that of any classical microwave radar of equal transmitted energy.

15:45	**526**	**Double Quantum Dots in an Undoped Germanium Heterostructure** *Andrea Hofmann [1], Daniel Jirovec [1], Andrea Ballabio [2], Jacopo Frigerio [2], Daniel Chrastina [2], Giovanni Isella [2], Georgios Katsaros [1]* *[1] IST Austria, [2] Politecnico di Milano* Hole spins in Germanium offer the possibility for record manipulation times due to the strong spin-orbit coupling. In addition, they should be largely immune to hyperfine noise. Here we present electrostatically defined quantum dots hosted in a two-dimensional Germanium hole gas. This approach provides excellent control over the measured system, which we can tune continuously from a single quantum dot to a double quantum dot. We demonstrate Pauli spin blockade and measure relevant material properties. From the large g-factor anisotropy we conclude that the confined states are mostly of heavy-hole type.
16:00	**527**	**Coupling spins coherently to microwave photons** *Thomas Ihn [1], Andreas Landig [1], Jonne Koski [1], Pasquale Scarlino [1], Udson Mendes [2], Alexandre Blais [2], Christian Reichl [1], Werner Wegscheider [1], Andreas Wallraff [1], Klaus Ensslin [1]* *[1] ETH Zürich, [2] Univ. de Sherbrooke, Canadian Inst. for Adv. Research* A resonant exchange qubit utilizes two orthogonal (S = 1/2, Sz = 1/2) states composed of three electron spins as the qubit states. We realize such a qubit in a GaAs triple quantum dot with each quantum dot hosting a single electron. We couple the electron spins strongly to individual GHz-photons in a strip-line resonator via a tunable electric dipole coupling. Under optimum conditions, the qubit is found to have a decoherence rate of less than 10 MHz at a qubit-resonator coupling strength of 23 MHz. In a further experiment, we use resonator photons to couple the resonant exchange qubit coherently to a superconducting transmon qubit.
16:30		***Coffee Break***
		Quantum Science and Technology IV *Chair: Lukas Sieberer, Uni Innsbruck*
17:00	**531**	**Shot-noise of high-impedance quantum devices using impedance matching** *Christian Schönenberger, Thomas Hasler, Gabriel Puebla-Hellmann, Vishal Ranjan, Cezar Harabula, Roy Haller, Minkyung Jung, Gergö Fülöp, University of Basel* High-impedance devices, such as quantum devices, are difficult to measure fast, due to the large impedance mismatch between the quantum device and 50 Ohm wave impedance of RF circuits. Fast and reliable read-out requires impedance matching, which is achieved through a resonant circuit. We compare two approaches, a) a lumped LC- and b) transmission line resonator on a quantum dot (QD) of which we measure its shot noise. We have tested the two approaches on QDs defined in a single carbon nanotube. We typically find suppressed shot-noise as expected for and in agreement with sequential tunneling through a QD. However, we also find regions of enhanced shot noise within and outside of Coulomb-blockade (CB). We explain this by blocking states.
17:15	**532**	**Electron-polariton interactions in the fractional quantum Hall regime** *Thibault Chervy [1], Patrick Knüppel [1], Sylvain Ravets [2], Stefan Fält [1], Martin Kroner [1], Werner Wegscheider [1], Atac Imamoglu [1]* *[1] Institute of Quantum Electronics, ETH Zürich, CH-8093 Zürich* *[2] Centre de Nanosciences et de Nanotechnologies (C2N), CNRS, Université Paris-Sud, Université Paris-Saclay* We investigate a two-dimensional electron system (2DES) embedded in an optical cavity. Cavity photons are strongly coupled to Fermi polarons, which leads to the formation of polaron-polaritons [1, 2, 3]. The light-matter coupling strength is sensitive to the electronic ground state. As the magnetic field is varied, we find that not only the energy of the polariton but also their scattering amplitude is changed. We observe nonlinear energy shifts in the lower and upper polariton lines at certain 2DES filling factors and concomitant enhancements in the electron-polariton scattering amplitude. [1] S. Ravets, et al., Phys. Rev. Lett. 120, 057401 (2018). [2] M. Sidler, et al., Nature Phys. 13, 255 (2017). [3] S. Smolka, et al., Science 346, 332 (2014).

17:30	**533**	**All fermionic non-Gaussian states are magic states for matchgate computations** *Barbara Kraus [1], Martin Hebenstreit [1], R. Jozsa [2], S. Strelchuk [2], M. Yoganathan [2]* *[1] Institute for Theoretical Physics, University of Innsbruck, Technikerstr. 21A, AT-6020 Innsbruck* *[2] DAMTP, University of Cambridge, Cambridge CB3 0WA, UK* Magic states were introduced in the context of Clifford circuits as a resource that elevates classically simulatable computations to quantum universal capability, while maintaining the same gate set. Here we study magic states in the context of matchgate (MG) circuits, where the notion becomes more subtle, as MGs are subject to locality constraints and also the SWAP gate is not available. Nevertheless a similar picture of gate-gadget constructions applies, and we show that every pure fermionic state which is non-Gaussian, i.e. which cannot be generated by MGs from a computational basis state, is a magic state for MG computations. This result has significance for prospective quantum computing implementation in view of the fact that MG circuit evolutions coincide with the quantum physical evolution of non-interacting fermions.
18:00	**534**	**The information theory of reference clocks** *Ralph Silva, Lennart Baumgaertner, Gilles Putz, Henrik Wilming, Yuxiang Yang, Renato Renner* *ETH Zürich* In this work we relate the physics of time to information theory via a simple question: how many bits of information do we gain when we read off the value of a clock? Our motivation is to understand from an operational point of view how much information clocks provide about time. Doing so would allow us to connect the performance of clocks with basic quantities in physics, such as size, energy and thermodynamic resources. Furthermore, this will be beneficial in establishing general results characterizing the cost of communication of time-information in clock networks. We present a measure of information based on a relative entropy between real clocks and "zero-information" clocks, and demonstrate that it unifies existing quantifiers of accuracy.
18:15	**535**	**Quantum interference of topological states of light** *Oded Zilberberg [1], Jean-Luc Tambasco [2], Giacomo Corrielli [3], Robert J. Chapman [2], Andrea Crespi [3], Roberto Osellame [3], Alberto Peruzzo [2]* *[1] ETH Zürich, [2] RMIT, [3] Milano* Topological insulators are materials that have a gapped bulk energy spectrum but contain protected in-gap states appearing at their surface. These states exhibit remarkable properties such as unidirectional propagation and robustness to noise that offer an opportunity to improve the performance and scalability of quantum technologies. For quantum applications, it is essential that the topological states are indistinguishable. We report high-visibility quantum interference of single-photon topological states in an integrated photonic circuit. Two topological boundary states, initially at opposite edges of a coupled waveguide array, are brought into proximity, where they interfere and undergo a beamsplitter operation. We observe Hong-Ou-Mandel interference with 93.1 ± 2.8% visibility, a hallmark nonclassical effect that is at the heart of linear optics–based quantum computation.
18:30	**536**	**Quantum Computing and Detection of Cancer** *Beatrix Hiesmayr, University of Vienna* New cutting edge technology developed in Poland allows obtaining the complete information from high energetic photons undergoing Compton scatterings. This in turn enables for the first time to read out the quantum information from the molecular environment, i.e. to study the quantum computing in metabolic processes in human beings. This new information may be related e.g. to cancer in humans as our pilot studies suggest.
19:00		***Postersession with Apéro***
20:30		

Time	ID	**Quantum Science and Technology V** *Chair: Laura Corman, ETH Zürich*
11:15	**541**	**Progress in the quantum control of single molecules** *Ziv Meir, Kaveh Najafian, Gregor Hegi, Mudit Sinhal, Stefan Willitsch, University of Basel* The development of methods for coherent manipulation of single isolated molecules has made rapid progress in recent years with exciting applications in the fields of precision spectroscopy, fundamental-physics-theories tests, atomic clocks and quantum-controlled chemistry. In this talk, I will describe our advances for achieving quantum control over a single molecule. In our experiment, a molecular beam is overlapped with a radio-frequency ion trap. We ionize nitrogen (N_2) molecules into a specific rotational-vibrational state. The molecular ion is co-trapped with an atomic ion for ground-state cooling and for molecular-state detection by entangling the molecular state with the atomic-ion motion. While we use N_2^+ as a prototype molecule, our methods can be extended to a general class of diatomic and polyatomic molecules.
11:45	**542**	**Atom Interferometry: Gravity, Blackbody Radiation and Dark Energy** *Philipp Haslinger [1], Viktoria Xu [2], Matt Jaffe [2], Osip Schwartz [2], Matthias Sonnleitner [3], Monika Ritsch-Marte [4], Helmut Ritsch [3], Holger Müller [2]* *[1] TU Wien, [2] UC Berkeley, [3] Uni Innsbruck, [4] Medizinische Uni Innsbruck* Atom interferometry has proven within the last decades its surprising versatility to sense with high precision tiniest forces. In this talk I will give an overview of our recent work using an optical cavity enhanced atom interferometer to sense with gravitational strength for fifths forces [1] and for an on the first-place counter-intuitive force due to blackbody radiation [2,3]. [1] M. Jaffe et al., Testing sub-gravitational forces on atoms from a miniature, in-vacuum source mass, Nat. Phys. 13 (2017) 938-942. [2] P. Haslinger et al., Attractive Force on Atoms due to Blackbody Radiation, Nat. Phys. 14 (2018) 257–260. [3] M. Sonnleitner et al., Attractive Optical Forces from Blackbody Radiation, PRL 111 (2013) 023601.
12:15	**543**	**Long-Baseline Universal Matter-Wave Interferometry** *Sebastian Pedalino [1], Yaakov Fein [1], Philipp Geyer [1], Filip Kialka [2], Patrick Zwick [3], Marcel Mayor [3], Stefan Gerlich [1], Markus Arndt [1]* *[1] Faculty of Physics, University of Vienna, [2] Faculty of Physics, University of Duisburg-Essen, [3] Department of Chemistry, University of Basel* We present the novel Long-Baseline Universal Matter-wave Interferometer (LUMI) in Vienna, a near-field, Kapitza-Dirac-Talbot-Lau type interferometer designed for quantum interference of high-mass molecules. It improves on an earlier Kapitza-Dirac-Talbot-Lau interferometer [1] by a factor of 10 in length and a factor 100 in inertial force sensitivity. The modular design of the experiment permits the in-vacuum exchange between optical and material diffraction gratings as well as the introduction of electric and magnetic fields, collision cells or spectroscopy lasers to explore the electronic, optical, magnetic and structural properties of a very diverse class of particles. We discuss new experiments with atoms, complex molecules and future prospects for high-mass clusters with improved precision over previous devices. [1] S. Gerlich et al., Nat.Phy.3, 711-715 (2007)
12:30	**544**	**Long-term stability analysis** **of a compact Ramsey-scheme vapor-cell atomic clock at 10^{-14} level** *Nil Almat, William Moreno, Florian Gruet, Christoph Affolderbach, Gaetano Mileti* *University of Neuchâtel* We are developing a highly compact and high-performance vapor-cell atomic clock operating in time-domain Ramsey scheme [1]. Here, we present an analysis of the dominant contributions to the clock instability at the level of 10^{-14}, on long-term timescales up to one day. Main limitations arise from light-shift effects, the barometric effect (i.e. the sensitivity to environmental pressure

		variations), and microwave power-shift effects. The full detailed instability budget will be discussed at the conference. The clock reaches a measured instability of $< 2 \times 10^{-14}$ at one day. 1 S. Kang, et al., Journal of Applied Physics 117, 104510 (2015).
12:45	**545**	**Towards spin-squeezing a solid** *Krzysztof T. Kaczmarek, Géraldine Haack, Jean Etesse, Alexey Tiranov, Florian Fröwis, Tamás Kriváchy, Nicolas Gisin, Mikael Afzelius, University of Geneva* The quantum-to-classical transition is one of the great frontiers of pure physics research. Generating large and long-lived entanglement is a path to exploring it. To reach this path we are using large ensembles of rare-earth ions doped into transparent crystals. Due to their appealing optical and microwave transitions, combined with unparalleled coherence properties, they have been a strong candidate for studying macroscopic entanglement. Here, we try to push the "macroscopicity" of the entangled state, both in atom number and coherence time, by spin-squeezing a large ensemble of Europium ions doped into Y_2SiO_5. To achieve this, we implement quantum non-demolition measurements on our solid-state system, using a frequency-domain optical interferometer. The generated spin-squeezed states will also be invaluable to quantum sensing.
13:00	**546**	**Cavity-Based 3D Cooling of a Levitated Nanoparticle via Coherent Scattering** *Dominik Windey [1], Carlos Gonzalez-Ballestero [2], Patrick Maurer [2], Lukas Novotny [1], Oriol Romero-Isart [2], Rene Reimann [1]* *[1] ETH Zürich, [2] Universität Innsbruck* Levitodynamics, studying the dynamics of levitated massive particles in vacuum, is currently finding applications in high-end sensing. Within fundamental physics, investigating quantum mechanics or thermodynamics at the mesoscale are driving forces of the emerging field. All these areas of levitodynamics rely on tightest control over the center-of-mass (c.m.) motion of the particle. Here, we experimentally realize [1] cavity cooling of all three c.m. motional degrees of freedom of a levitated nanoparticle in vacuum. The particle is trapped in an optical tweezer and is cooled by coherently scattering tweezer light into the cavity mode. We discuss [2] methods, limits, and opportunities of our approach. [1] Phys. Rev. Lett. 122, 123601 (2019) [2] arXiv:1902.01282 (2019)
13:15		***END***

ID	Quantum Science and Technology Poster
551	**Fabry-Pérot interference in InAs/GaSb quantum wells** *Michele Masseroni, Matija Karalic, ETH Zürich* The observation of interference phenomena in two-dimensional mesoscopic systems is difficult, and so far constrained to graphene, where certain mechanisms originating in the graphene band structure strengthen the emergence of this phenomenon. Here, we report on the experimental observation of Fabry-Pérot oscillations in electrostatically defined cavities in InAs/GaSb quantum wells. Carriers travelling through the cavity are reflected at the interfaces, leading to interference. The emergence of the interference is a consequence of the band inversion and electron-hole hybridization. Our work expands the field of electron optics to a rich class of two-dimensional systems with tunable band structure.
552	**Investigating coherence limitations in transmon qubits** *Matthias Mergenthaler, Clemens Müller, Marc Ganzhorn, Stephan Paredes, Peter Müller, Stefan Filipp, Andreas Fuhrer, IBM Research Zurich* The last decades have seen significant advances in coherence times of superconducting qubits. This was mainly made possible by reducing charge dispersion of transmon qubits, better thermalization and filtering of the readout and control circuitry as well as improvements in Josephson junction fabrication. Lately, efforts are being made in order to investigate limitations of coherence due to material interfaces and two level fluctuators [1-3].

Here we present our work towards understanding decoherence mechanisms in transmon qubits via surface treatments and sample packaging. We show qubit packaging under UHV or a controlled atmosphere, study surface treatments and discuss coherence data from measured devices.

[1] J. M.Gambetta, et al., IEEE Trans.Appl.Supercond., 27, (2016).
[2] S. DeGraaf et al., Nat.Communications 9, (2017)
[3] C. Müller et al., arXiv:1705.01108 (2017)

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Optimal Control of Superconducting Qubits

Max Werninghaus [1], Federico Roy [2], Daniel J. Egger [1], Marc Ganzhorn [1], Shai Machnes [2], Frank Wilhelm-Mauch [2], Stefan Filipp [1]
[1] IBM Research Zurich, [2] Saarland University

Fast and accurate two-qubit gates are a key requirement to perform complex algorithms on current quantum computers. Typical gates have errors less than 5% and take around 200 ns. Shorter gates result in unwanted leakage out of the computational subspace. Optimal control theory aims to design fast control pulses that suppress side effects such as cross talk and leakage. However, even with an accurately calibrated system model, control pulses require a tune-up to accommodate for parameter drifts and model inaccuracies. Here, we present our work on methods to simultaneously calibrate control pulses defined by up to 20 parameters. We improve the interplay between the control instruments and the multidimensional optimization algorithms to reduce the hardware constraints to realize efficient tune-up feedback-loops.

554

Entanglement in special relativistic settings

Christoph Schöberl, Universität Wien

This poster studies the entanglement of two and three spin 1/2 particles in (special) relativistic settings, in particular for inertial observers at rest relatively to the entangled particles and in a Lorentz-boosted frame. Here spin and momentum degrees of freedom of the particles can be viewed as 4-qubit and 6-qubit states, respectively. These states are analysed in terms of their entanglement properties, i.e. how the entanglement is affected for a Lorentz-boosted observer. It turns out that there are partitions for which the entanglement is invariant, for others the opposite is true. Also the effect of Lorentz boosts on Bell-inequalities is investigated.

555

Quantum informational analysis of neutrino oscillations via Leggett-Garg inequalities

Christiane Schultze, Universität Wien

The oscillation of neutrinos was predicted in the mid of the last century. Since then they were intensively studied both theoretically and experimentally since a couple of phenomena like e.g. CP violation (charge-conjugation-parity) are conjectured. Also, it is not known which neutrino is the heaviest, formulated as the mass hierarchy problem. I will focus on how tools from foundations of quantum mechanics can give answers to these riddles in neutrino physics. In particular, a type of the Leggett-Garg inequalities, kind of time-like versions of Bell inequalities, will be investigated for neutrinos propagating through matter.

556

Investigating noise sources with a triple quantum dot charge qubit

Benedikt Kratochwil [1], Jonne Koski [1], Andreas Landig [1], Pasquale Scarlino [1], José Abadillo-Uriel [2], Christian Reichl [1], Werner Wegscheider [1], Susan Coppersmith [3], Mark Friesen [2], Andreas Wallraff [1], Klaus Ensslin [1], Thomas Ihn [1]
[1] ETH Zürich, [2] University of Wisconsin-Madison, [3] University of New South Wales

We implement a single electron charge qubit in a gate defined linear triple dot array on a GaAs/AlGaAs heterostructure [1,2]. The qubit is strongly dipole-coupled to photons in a high impedance frequency tunable superconducting resonator. We operate the qubit at a higher order sweet spot along one of the detuning axes. Measuring the qubit coherence for different qubit configurations we acquire information about the dominant noise source in our system.

[1] A. J. Landig et al.,arXiv: 1903.04022 (2019)
[2] J. V. Koski et al, Manuscript in preparation

557	**Measurable Inequalities for higher dimensional Quantum Secret Sharing Protocols** *Michael Partener, Beatrix Hiesmayr, University of Vienna* Distributing a secret to many parties such that none alone can reveal it was first proposed by Shamir (1979) and applied in the quantum scheme by Hillery, Bužek and Berthiaume (1999). By a modification of this HBB protocol Hiesmayr, Huber and Schauer showed that the security against eavesdropping or a dishonest party can be based on the physical property due to entanglement, more precise genuine multipartite entanglement of the Greenberger-Horne-Zeilinger-type. In this poster we extend the protocol to higher dimensional quantum systems, show that they provide more aspects and study its security by inequalities witnessing the specific genuine multipartite entanglement.
558	**Dissipative time-crystal phase in parametrically unstable optical cavities** *Kilian Robert Seibold, Riccardo Rota, Vincenzo Savona, EPFL* We explore theoretically the behavior of two coupled nonlinear photonic cavities, in presence of inhomogeneous coherent driving and local dissipations. By solving numerically the quantum master equation, we extrapolate the properties of the system in a well defined thermodynamical limit of large photon occupation. We focus on the peculiar regime where the mean field Gross-Pitaevskii approach predicts a unique parametrically unstable steady-state solution. Here, the dynamics of the open quantum system exhibits a time cristal behavior characterized by the presence of purely imaginary eigenvalues in the spectrum of the Liouvillian superoperator at the thermodynamical limit. When the amplitude of the inhomogeneous driving is changed, we observe the emergence of two dissipative phase transitions from the time cristal to the fully classical coherent phase.
559	**Entangled two-photon absorption and the quantum advantage in sensing** *Dmitry Tabakaev, Géraldine Haack, Robert Thew, Hugo Zbinden, Université de Genève* The recently developed theory of entangled two-photon absorption (ETPA) predicts a linear dependence of its rate on the entangled pair flux in the low-power regime, and provides a tool for two-photon studies even on sensitive samples. We experimentally observed this signature for ETPA-induced fluorescence of Rhodamine 6G and its dependence on inter-photon delay, concentration and polarization to find out which degrees of freedom play a role in ETPA. The developed methods have possible applications in sensing, spectroscopy, imaging and fluorescence microscopy, especially for biological objects in vivo, that could be susceptible to damage from intense laser schemes.
560	**Spin detection through parametric mode coupling in nanomembranes** *Jan Kosata [1], Oded Zilberberg [1], Ramasubramanian Chitra [1], Albert Schliesser [2], Christian L. Degen [1], Alexander Eichler [1]* *[1] ETH Zürich, [2] Niels Bohr Institute, Copenhagen University* Nanomechanical resonators with high quality factors and noise isolation are promising candidates for pushing the frontiers of magnetic resonance force microscopy towards single-spin detection. Single spin detection using state-of-the-art MRFM is hampered by the intrinsic weakness of the kHz-range signal and its frequency mismatch with the MHz-range resonators used to detect it. An alternate sensing scheme is developed here which uses the normal modes of coupled, parametrically driven oscillators, achieving simultaneous amplification of the signal and its frequency conversion. Furthermore, nonlinear corrections to the model predict critical regimes with striking signal-dependent features in the response function, opening up novel weak-force measurement paradigms. Our sensing scheme can be easily implemented using nanomechanical membranes.
561	**Quantum dynamics of an ultracold ion coupled to a nanomechanical oscillator** *Moritz Weegen, Panagiotis Fountas, Martino Poggio, Stefan Willitsch, University of Basel* We present the coupling of a trapped ion to a nanomechanical oscillator/nanowire in order to study new methods for the preparation of complex motional quantum states that might be challenging to produce by conventional optical means. The quantum dynamics of such a hybrid system have been studied theoretically showing possibilities of creating coherent states, as well as purely non-classical states such as cat-states and others. Here, we discuss the prospects of this approach and its experimental implementation.

562	**Quantum-Logic Assisted Molecular Precision Measurements Using a Network for the Distribution of the Swiss Frequency Standard** *Aleksandr Shlykov, Ziv Meir, Gregor Hegi, Kaveh Najafian, Mudit Sinhal, Stefan Willitsch* *University of Basel* The application of quantum-logic techniques to the spectroscopy of trapped molecular ions has enabled the determination of molecular properties at unprecedented levels of precision. Molecules have been proposed as suitable candidates for testing possible time-variation of fundamental constants and precision testing of QED. Further advancement in the measurement accuracy will be enabled through the implementation of network for the distribution of the Swiss frequency standard. We are currently establishing a complete toolbox for high-precision spectroscopy of single molecules using quantum-logic methods, their initialization, coherent manipulation and non-destructive interrogation by coupling them to a co-trapped single atomic ion. We have laid the experimental and theoretical foundations for hyperfine-state initialization of the molecular ions and addressing the suitable extremely narrow infrared transitions.
563	**Classical many-body time crystals** *Toni Heugel, Matthias Oscity, Alexander Eichler, Oded Zilberberg, Ramasubramanian Chitra* *ETH Zürich* Discrete time crystals are a many-body state of matter where time translation symmetry is spontaneously broken in a periodically driven system. In view of the intense debate regarding the minimal requirements for the realization of a discrete time crystal, here we present a very pedagogical example of a many-body time crystal using coupled parametric resonators. We use classical bifurcation theory to study this resonator network and provide a clear distinction between an effective *single mode* and a truly *many body* time-translation symmetry breaking. We experimentally demonstrate this paradigm using two coupled mechanical oscillators, thus providing a clear route for time crystals realizations in real materials.
564	**Cavity Exciton-Polariton Condensates in Engineered Potential Landscapes at Room Temperature** *Fabio Scafirimuto [1], Michael Becker [1], Darius Urbonas [1], Ullrich Scherf [2], Thilo Stöferle [1], Rainer F. Mahrt [1]* *[1] IBM Research-Zurich, [2] Bergische Universität Wuppertal* We create exciton-polariton condensates in engineered potential landscapes at room temperature by optically exciting a ladder-type conjugated polymer placed inside a tunable optical microcavity. In the upper mirror of the cavity we define multiple in-plane structures (from single defects to lattices). By exciting the system above threshold, we observe polariton condensation. Condensation features such as non-linear emission and linewidth narrowing are shown. Energy dispersions in k-space as well as temporal and spatial coherence are studied for different states by detuning the cavity. Our results represent a step towards the realization of a polariton simulator at ambient conditions.
565	**Bidirectional Microwave to Optical Gaussian Quantum State Transfer** *Alfredo Rueda, William Hease, Shabir Barzanjeh, Johannes Fink* *Institute of Science and Technology Austria* We propose a triply-resonant electro-optic modulator as an efficient stationary source of entangled microwave and optical radiation, based on a mm-sized high optical *Q* lithium niobate whispering gallery mode resonator (WGMR) coupled to a superconducting 3D microwave cavity. The creation of entangled microwave and optical photons is possible via spontaneous parametric down conversion (SPDC) in the lithium niobate WGMR. By profiting from the resonance intensity build-up of the modes, the device can achieve creation rates of 10^6 entangled bits/s for conservative system parameters at optical pump powers in the order of tens of μW. Furthermore, the implementation of this device as an Einstein-Podolski-Rosen source in a Braunstein-Kimble teleportation set-up allows quantum state transfer between microwave and optical Gaussian states.
~~**566**~~	*moved to talk 508*

567	**Integrating a fiber cavity along the axis of a linear ion trap** *Klemens Schüppert [1], Markus Teller [1], Viktor Messerer [1], Yueyang Zou [1], Dario A. Fiorette [1], Maria Galli [1], Yunfei Pu [1], Jakob Reichel [2], Rainer Blatt [1,3], Tracy Northup [1]* *[1] Institut für Experimentalphysik, Universität Innsbruck, Austria* *[2] Laboratoire Kastler Brossel, ENS/CNRS/UPMC/CdF Paris, France* *[3] Institut für Quantenoptik und Quanteninformation, Austria* Interfaces between stationary and traveling qubits are fundamental building blocks for quantum networks. Cavities are an established approach for an efficient interface; here, we use a fiber cavity to couple trapped ions to photons. Fiber cavities enable access to the strong coupling regime, allowing quantum communication to be carried out over long distances with high fidelity and efficiency. To couple multiple ions, we have designed an ion-cavity system in which fibers are integrated inside electrodes along the axis of a linear Paul trap. As an intermediate step, we have measured heating rates and micromotion of our trap in the absence of fibers. After reassembling the trap with the fiber cavity, we are currently characterizing the full system.
568	**High-rate photon pairs and sequential Time-Bin entanglement with Si_3N_4 ring microresonators** *Farid Samara [1], Anthony Martin [1], Claire Autebert [1], Maxim Karpov [2], Tobias Kippenberg [2], Hugo Zbinden [1], Rob Thew [1]* *[1] Université de Genève, [2] EPFL* Integrated photonic sources represent a key building block as practical, low-cost, schemes for quantum communication. In the context of photon pair sources, microring-resonators (MRR) are emerging as a viable solution for integrated photon pair sources with advantages for multiplexing and high dimensional entanglement generation. By exploiting MRR as a photon pair source, sequential time-bin entanglement is generated with 750 MHz pump rate and interference fringes with raw visibility up to 98%. Detected coincidence counts rate of up to 80 kHz was achieved by relying on low loss commercial telecom filters, and state of the art superconducting single photon detectors. We also present several techniques that we have incorporated to characterise and mitigate noise while improving pump rejection and channel selection.
569	**Optical spin-wave storage in a paramagnetic solid state crystal** *Moritz Businger [1], Alexey Tiranov [1], Antonio Ortu [1], Sacha Welinski [2], Alban Ferrier [2], Philippe Goldner [2], Nicolas Gisin [1], Mikael Afzelius [1]* *[1] Université de Genève, [2] Chimie Paris Tech* Solid-state electronic spins are promising candidates for various applications in quantum information science, such as quantum communication and computation. However, due to their strong magnetic dipoles they are quite susceptible to magnetic noise, which usually limits their coherence lifetimes. Here we demonstrate the storage of a 100 ns optical pulse in a $^{171}Yb^{3+}:Y_2SO_5$ paramagnetic crystal for more than 1 millisecond. For this we utilize the microwave and optical clock transitions that are present in this material at zero magnetic field. The large hyperfine splittings make this system promising as a broadband quantum memory, and potentially couple for coupling of spin systems to superconducting qubits.
570	**Coupled Quantum Dots in Bilayer Graphene with Tunable Barriers** *Chuyao Tong [1], Marius Eich [1], Rebekka Garreis [1], Annika Kurzmann [1], Yongjin Lee [1], Riccardo Pisoni [1], Peter Rickhaus [1], Takashi Taniguchi [2], Kenji Watanabe [2], Thomas Ihn [1], Klaus Ensslin [1]* *[1] ETH Zürich, [2] National Institute for Material Science* Exploiting the band-gap induced by perpendicular electric fields, charge carriers in bilayer graphene can be confined via electrostatic gating. This realization provides a versatile and tunable platform hosting carbon-qubits. We confine charge carriers to a narrow channel, defined by lateral gating. Another layer of gates, perpendicular to the transport direction, locally tune the carrier density in this channel. They serve as either plunger gates or tunnel barriers. A range of coupled multi-dot systems are formed, where the occupation can be tuned to the few-carrier regime in single dots. The tunnel couplings can be varied by more than two orders of magnitude, allowing us to study fully tunable quantum dot arrays of arbitrary polarities and couplings.

571	**Accuracy enhancing protocols for quantum clocks** *Yuxiang Yang, Lennart Baumgaertner, Ralph Silva, Renato Renner, ETH Zürich* The accuracy of time information generated by clocks can be enhanced by allowing them to communicate with each other. Here we consider a basic scenario where a quantum clock receives a low-accuracy time signal as input and ask whether it can generate an output of higher accuracy. We propose protocols that, using a clock with a d-dimensional state space, achieve an accuracy enhancement by a factor d (for large d). If no feedback on the input signal is allowed, this enhancement is temporary. Conversely, with feedback, the enhancement can be retained for longer. The protocols may be used to synchronise clocks in a network and define a time-scale that is more accurate than that achieved by non-interacting clocks.
572	**Can quantum algorithms in chemistry outperform their classical equivalent? Advanced Quantum Unitary Coupled Cluster methods for strongly correlated systems.** *Igor Sokolov, IBM Zurich Rüschlikon* The truncated classical coupled cluster (CC) methods have been known to provide non-variational energies in the systems that present multiconfigurational nature of the ground state. Methods such as paired CC (pCC) and singlet CC (CC0) unreliably correct this failure by eliminating excitations in the cluster operator. In this work, we show that their unitary implementation (q-pUCC, q-UCC0) on digital quantum computers (QC) using the variational quantum eigensolver algorithm (VQE) with a single Trotter step unconditionally cures the breakdown of their classical counterparts. In addition, the q-UCC0 reproduces the geometric features of the exact energy landscape more accurately than the quantum pCC (q-pUCC) method. Moreover, we propose a selection criterion that improves on the existing MP2 amplitude-based selection scheme by eliminating the single excitations which enables the optimiser to recover the correlation energy in less iterations. The robustness of these methods is tested on the H_4, H_2O, N_2 molecules and the repulsive Hubbard model, in a QC simulator, Qiskit, using various qubit and circuit depth reduction schemes which are currently necessary for the implementation on the NISQ hardware.
573	**Strong magneto-mechanical coupling** *David Zöpfl, Uni Innsbruck & IQOQI* In our experiment, we inductively couple a mechanical oscillator to a microwave circuit. Our magnetic cantilever leads to a position dependent magnetic field. This field is coupled to a microwave resonator via an embedded SQUID i.e. the resonance frequency depends on flux and consequently on the position of the cantilever. Our first devices indicate a single photon coupling strength of up to 3 kHz (mechanical frequency around 300 kHz). In the near future, we want to investigate cooling of our mechanical cantilever –- a macroscopic object, eventually reaching the quantum ground state.
574	**Dimerized states and dynamical instabilities in a blue-detuned cavity-BEC system** *Rui Lin [1], Paolo Molignini [1], Ramasubramanian Chitra [1], Axel Lode [2]* *[1] ETH Zürich, [2] Atominstitut, TU Wien & Wolfgang-Pauli-Institut, Universität Wien* We numerically study a weakly-interacting, harmonically-trapped boson gas coupled to a high-finesse optical cavity. The bosons self-organise into a lattice when the driving laser is strong enough. When the cavity is blue-detuned, we observe dimerization of lattice sites which leads to states with different atomic correlations. With an even stronger pumping laser, the system is driven into dynamical instabilities, where strange attractor and chaos are observed. Such instabilities are related to Neimark-Sack bifurcation. However, the strange attractor behaviours are extremely vulnerable in the presence of atomic fluctuations and a tight harmonic trap.

575	**Qubit-losses in topological quantum computers: An experimental toolbox**
	Roman Stricker, University of Innsbruck, Institute for Experimental Physics
	The loss of qubits - the elementary carriers of quantum information - poses one of the fundamental obstacles towards large-scale and fault-tolerant quantum information processors. We demonstrate an experimental toolbox for ion-qubit control and implement a full cycle of qubit-loss detection and correction on a minimal instance of the topological surface code. This includes a quantum non-demolition measurement of a qubit-loss event, triggering an in-circuit conditional code-switching operation. This enables the restoration of encoded logical information by mapping it onto a new quantum correcting code on a reduced number of qubits. Together with techniques to correct computational errors, this constitutes essential building blocks for complete and scalable quantum error correction.