Tuesday, 01.09.2015, Room EI 8

Time	ID	I: MOLECULES, ATTO-, FEMTO-SECOND SPECTROSCOPY Chair: Antoine Weis, Uni Fribourg
13:30	501	**Identification of excited states in alkali – alkaline earth molecules by combination of theory and experiment** *Johann Pototschnig [1], Wolfgang Ernst [1], Andreas Hauser [1], Florian Lackner [2]* *[1] Institute of Experimental Physics, Graz University of Technology, Petersgasse 16, AT-8010 Graz* *[2] UXSL, Lawrence Berkeley National Lab., 1 Cyclotron Road Mailstop 2-300, 94720 Berkeley, USA* Ab initio calculations were performed to determine the properties of excited states in alkali-alkaline earth diatomic molecules. These results were compared to measurements by helium nanodroplet isolation spectroscopy. On one hand, the calculations help with the interpretation of spectral features, on the other hand, the experimental data provide information about the accuracy of the calculations. Results for the molecules RbSr and RbCa will be presented. For laser induced fluorescence measurements, the inclusion of spin-orbit interaction was necessary to obtain agreement between theory and experiment. Knowledge of the excited states will be important for future experiments.
13:45	502	**The Influence of Resonances in Multiphoton Probing of Molecular Dynamics** *Markus Koch [1], Thomas Wolf [2], Markus Gühr [2]* *[1] Institute of Experimental Physics, TU Graz, Petersgasse 16, AT-8010 Graz* *[2] PULSE, SLAC National Accelerator Laboratory, 2575 Sand Hill Road, 94025 Menlo Park, USA* Ultrafast electronic and nuclear relaxation processes in molecules can be studied with femtosecond pump-probe experiments. After photoexcitation the relaxation dynamics are probed with a second, time-delayed probe pulse to ionize the molecules. Here we present dynamical studies on perylene molecules [1] where we compare single photon ionization using high photon energies to multiphoton ionization, a widely applied probe method. We find that the transient multiphoton signal is strongly influenced by resonant excited states and that each method on its own might lead to a misinterpretation of the experimental results. [1] M. Koch, T. J. A.Wolf, M.Gühr, PRA,91,031403
14:00	503	**Molecular Dissociation Induced by Stimulated Raman Scattering** *Seyedreza Larimian [1], Sonia Erattupuzha [1], Feng He [2], Stefan Roither [1], Daniil Kartashov [1], Li Zhang [1], Andrius Baltuska [1], Markus Kitzler [1], Xinhua Xie [1]* *[1] Photonics Institute, Vienna University of Technology, Gusshausstrasse 27/387, AT-1040 Vienna* *[2] Department of Physics, Shanghai Jiao Tong University, CN-200240 Shanghai* Raman scattering is a process involving inelastic scattering of a photon with an atom or a molecule. This process has broad applications in spectroscopy and laser physics. Here we report on the experimental control of the dissociation of hydrogen in two-color laser fields by stimulated Raman scattering. We found that H_2^+ in low-lying vibrational states of the ground electronic state can reach high-lying vibrational states near the dissociation threshold by absorbing a 400 nm photon and emitting an 800 nm photon. From these high-lying vibrational states H_2^+ may dissociate with a near-zero kinetic energy release.
14:15	504	**Strong-field control of molecular processes** *Sonia Erattupuzha [1], Seyedreza Larimian [1], Markus Schöffler [1], Markus Koch [2], Andrius Baltuska [1], Xinhua Xie [1], Markus Kitzler [1]* *[1] Photonics Institute, Vienna University of Technology, Gusshausstrasse 27/387, AT-1040 Vienna* *[2] Institute for Experimental Physics, Graz University of Technology, Petersgasse 16, AT-8010 Graz* When a molecule interacts with a strong laser field multiple ionization may take place. In this process the final ionic state may be reached via different pathways, which may give rise to strongly different nuclear dynamics on the intermediately populated potential energy surfaces. We report on experiments

		that employ a sequence of two delayed pulses for controlling and visualizing this nuclear dynamics in CO_2. Intense laser pulses can also mediate a process where a detached electron is recaptured by the parent ion preparing it in highly-excited states. We study this recapture-process in Argon dimers and investigate its amenability for strong-field-control.
14:30	**505**	**Attosecond and femtosecond X-ray absorption spectroscopy in the 50-200 eV and in the 1-3.5 keV energy ranges** *Enikoe Seres, Georg Winkler, Jozsef Seres* *Technische Universität Wien, Stadionallee 2, AT-1020 Vienna* We present our experimental results of time-resolved X-ray spectroscopy in Krypton gas in the femto- and attosecond regime in the 60-200 eV, using the high-order harmonics generated in He gas by a Ti:sapphire laser system. These results will be compared to earlier femtosecond He and Ne results in the first 1-3.5 keV regime. We focus on the spectroscopy of laser dressed atoms – by highlighting the positive effect of X-ray parametric applications on X-ray photon yield. C. Ott et al., Nature 374,516(2015); E. Seres et al., Appl.Phys A 46,43-50(2009); C. Serrat et al., Oprics Express 23,4(2015)
14:45	**506**	**Attosecond Spatial Control of Electron Wavepackets** *Markus Kitzler [1], Xinhua Xie [1], Li Zhang [1], Stefan Roither [1], Sonia Erattupuzha [1], Daniil Kartashov [1], Paul B. Corkum [2], Andrius Baltuska [1], André Staudte [2]* *[1] Photonics Institute, Vienna University of Technology, Gusshausstrasse 27/387, AT-1040 Vienna* *[2] National Research Council of Canada, 100 Sussex Drive, CA-Ottawa, K1A0R6* Angström and attosecond control of free electron wave packets is one of the pinnacles of attosecond science. Orthogonally polarized two-color (OTC) laser fields allow controlling the motion of field-ionizing electronic wave packets and both in time and space and therewith establish an attosecond time-scale in the polarization plane. We report on experiments that use OTC pulses for studying single and double ionization of neon using coincidence momentum imaging. We gain access to the Coulomb influence in single ionization on sub-cycle times, and in double ionization we demonstrate switching between a correlated and a strongly anti-correlated two electron emission dynamics.
15:00		
15:30		***Coffee Break***

Wednesday, 02.09.2015, Room EI 8

Time	ID	**II: Quantum Information** *Chair: Peter Rabl, TU Wien*
13:30	**511**	**Photonic time-energy entangled qudits from various discretization schemes** *André Stefanov, Sacha Schwarz, Bänz Bessire, Stefan Lerch* *Institute of Applied Physics, University of Bern, Sidlerstrasse 5, CH-3012 Bern* We present an experimental scheme derived from a classical pulse-shaping to manipulate entangled qudits encoded in energy. Several quantum information protocols were realized including quantum state tomography [PRA, 88, 032322(2013)], quantum state estimation [Opt. Lett., 39, 5399(2014], violation of Bell-type inequalities [IJQI, 12, 1560026(2015)] and quantification of non-locality by the minimal amount of classical communication required to simulate the correlations [JPA, 47, 424013(2014]. We show the flexibility of the setup by encoding, with the same setup, energy-bins and time-bins, but also other energy modes, like the Schmidt modes [NJP, 16, 033017(2014)].
13:45	**512**	**Information-theoretic noise and disturbance uncertainty relations for qubits studied in neutron spin measurements** *Bülent Demirel, Atominstitut, Technische Universität Wien, Stadionalle 2, AT-1020 Wien* Since Heisenberg's original formulation of the uncertainty relation a lot of new definitions were constituted. An information-theoretic concept for noise and disturbance in quantum measurements was introduced recently and thereby a state-independent noise-disturbance uncertainty relation was

proposed. This relation quantifies error and disturbance using the notion of information theoretical entropy as introduced by Shannon. Here, I present a tight noise-disturbance uncertainty relation for qubits and show results of an experimental test carried out with neutron. Final results show that the tight noise-disturbance uncertainty relation for qubits is saturated when an optimal correction procedure is applied.

14:00 **513**

A single-photon Ramsey-interferometer

Sven Ramelow, Stephane Clemmen, Alessandro Farsi, Alexander Gaeta
School of Applied and Engineering Physics, Cornell University, Clark Hall, 14853 Ithaca, NY, USA

Interferometry using discrete energy levels of atoms, molecules or nuclei is the foundation for a wide range of physical phenomena and enables important techniques such as nuclear magnetic resonance, electron spin resonance, or Ramsey interferometry. It is essential for quantum information processing because most qubits are encoded as energy superposition states of single quantum systems. Here, we demonstrate interference of discrete energy levels of a single photon. We experimentally generate single photon energy superposition states, and realize unitary transformations and arbitrary projective measurements, allowing us to implement a high-visibility single-photon Ramsey interferometer. We anticipate our findings will create novel insights and applications for frequency-encoded photonic quantum information.

14:15 **514**

Exotic entanglement with twisted photons

Mehul Malik [1], Manuel Erhard [1], Mario Krenn [1], Robert Fickler [1], Marcus Huber [2], Anton Zeilinger [1]
[1] University of Vienna, Boltzmanngasse 3, AT-1090 Vienna
[2] Universitat Autonoma de Barcelona, Bellaterra, ES-08193 Barcelona

Initially proposed as a two-particle problem, the concept of entanglement was extended to three particles by Greenberger, Horne, and Zeilinger in 1989. To date, experimental realizations of multipartite states have been limited to two dimensions due to the use of polarization-entangled photons. When the dimensionality of such states is increased, a richer entanglement structure emerges. In such "exotic" entangled states, the dimension of each component particle can be different. The orbital angular momentum of photons offers a discrete, high-dimensional Hilbert space for realizing such states. We describe the experimental generation of a high-dimensional, three-particle state using the OAM degree of freedom.

14:30 **515**

Improvement of the polarized neutron interferometer setup demonstrating violation of a Bell-like inequality

Hermann Geppert, Tobias Denkmayr, Stephan Sponar, Hartmut Lemmel, Yuji Hasegawa,
Atominstitut,TU Wien, Stadionallee 2, AT-1020 Vienna

For precise measurements with polarized neutrons high effcient spin-manipulation is required. We developed several neutron optical elements suitable for a new sophisticated setup, i.e., DC spin-turners and Larmor-accelerators which diminish thermal disturbances and depolarisation considerably. The gain in performance is exploited demonstrating violation of a Bell-like inequality for a spin-path entangled single-neutron state. The obtained value of S = 2:365(13), which is much higher than previous measurements by neutron interferometry, is 28 σ above the limit of S = 2 predicted by contextual hidden variable theories. The new setup is more flexible referring to state preparation and analysis, therefore new, more precise measurements can be carried out.

14:45 **516**

Twisted photon entanglement through turbulent air across Vienna

Mario Krenn, Johannes Handsteiner, Matthias Fink, Robert Fickler, Anton Zeilinger
Faculty of Physics, University of Vienna, Boltzmanngasse 5, AT-1090 Vienna

Spatial modes of photons offer a large state-space, useful for long-distance (quantum) communication. However, numerous investigations predict significant degradation during propagation, questioning the feasibility for such schemes. In 2014, we performed the first experiment of visible light in a real-world scenario, where we transmitted classical information encoded in spatial modes at a distance of 3 kilometers across the city of Vienna. Here we present our follow-up experiment, which brings our investigation to the quantum level. We show that quantum entanglement can be detected after a long-distance transmission, paving the way for further investigation of quantum communication with large alphabets.

15:00	**517**	**Coherent controlization in superconducting qubits** *Nicolai Friis [1], Alexey Melnikov [1], Gerhard Kirchmair [2], Hans Jürgen Briegel [1]* *[1] Insitut für Theoretische Physik, Universität Innsbruck, Technikerstraße 21a, AT-6020 Innsbruck* *[2] Insitut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25, AT-6020 Innsbruck* Coherent controlization, i.e., coherent conditioning of arbitrary single- or multi-qubit operations on the state of one or more control qubits, is an important ingredient for the flexible implementation of many algorithms in quantum computation. This is of particular significance when subroutines are unknown or frequently modified, such as in decision-making algorithms for learning agents. We propose a scheme to realize coherent controlization for any number of superconducting qubits coupled to a microwave resonator. We present an explicit construction for two and three qubits, and demonstrate its feasibility, taking into account losses, dephasing, and the cavity self-Kerr effect.
15:15		
16:00		***Coffee Break***
		III: Fundamental physics, experimental methods *Chair: Markus Arndt, Uni Wien*
16:30	**521**	**An atomic hydrogen beam to test ASACUSA's apparatus for antihydrogen spectroscopy** *Martin Diermaier [1], Christian B. Jepsen [2], Bernadette Kolbinger [1], Chloe Malbrunot [3], Oswald Massiczek [1], Clemens Sauerzopf [1], Martin C. Simon [1], Johann Zmeskal [1], Eberhard Widmann [1]* *[1] Stefan-Meyer-Institute for Subatomic Physics, Boltzmanngasse 3, AT-1090 Wien* *[2] Niels Bohr Institute, University of Copenhagen, Blegdamsvej 17, DK-2100 Copenhagen* *[3] CERN, Geneva 23, CH-1211 Geneva* The ASACUSA collaboration aims to measure the ground state hyperfine splitting of the antihydrogen atom, since this is a system where the CPT symmetry can be investigated with extremely high sensitivity. During the CERN LS1 shut down, antiprotons were not available. Therefore, a source of cold, polarised, and modulated atomic hydrogen has been constructed to enable comprehensive testing of the Rabi-like experimental setup consisting of a microwave spin flip cavity and superconducting sextupole magnet. In this talk I will present the latest experimental data of the measurements with atomic hydrogen where we determined the ground state hyperfine splitting with a precision on the 10 ppb level.
16:45	**522**	**Quantum diffraction an ultra-thin gratings: the role of a permanent dipole moment** *Christian Knobloch [1], Christian Brand [1], Markus Arndt [1], Benjamin Stickler [2], Klaus Hornberger [2], Michele Sclafani [3], Thomas Juffmann [4], Lisa Wörner [1], Ori Cheshnovsky [5], Yigal Lilach [5]* *[1] Quantum Nanophysics Gr., Faculty of Physics, Univ. of Vienna, Boltzmanngasse 5, AT-1090 Vienna* *[2] Faculty of Physics, University of Duisburg-Essen, Lotharstraße 1, DE-47048 Duisburg* *[3] ICFO - Inst. of Photonic Sciences , Mediterranean Technology Park , Av. Carl Friedrich Gauss 3, ES-08860 Castelldefels* *[4] Department of Physics, Stanford University, 450 Serra Mall, 94305 Stanford, USA* *[5] School of Chemistry, Tel Aviv University, School of Chemistry, IL-69978 Tel Aviv* Quantum matter waves of massive molecules are expected to be sensitive to interactions due to their rich number of internal degrees of freedom. Here we study the influence of a molecular dipole moment on matter wave diffraction. We send polar and non-polar molecules of similar mass through nanomechanical gratings and detect the resulting quantum interference. We find that a molecular permanent electric dipole moment provides an efficient channel for phase-averaging which sets constraints to matter wave experiments on biomolecules.
17:00	**523**	**Coherent coupling of distant nitrogen-vacancy ensembles via a superconducting quantum bus** *Thomas Astner, Atominstitut, Technische Universität Wien, Stadionallee 2, AT-1020 Vienna* The spin degree of freedom has shown to be an excellent carrier of quantum information due to its small size. In particular the nitrogen-vacancy defect in diamond has shown to have excellent coherence properties.On the contrary, it is very hard to couple two nitrogen-vacancy spins in a deterministic

		way. Until now, nitrogen-vacancy spins have been coupled via dipole-dipole coupling on the nanometer scale or via heralded photons. Here we present an experiment that demonstrates the strong coherent coupling of two nitrogen-vacancy ensembles that are separated several centimeters. The coupling is provided via a superconducting transmission line resonator.
17:15	**524**	**Cooling, lasing and PT-symmetry breaking phenomena with nitrogen-vacancy centers in diamond nanoresonators** *Peter Rabl, TU Wien, Stadionallee 2, AT-1020 Wien* Diamond has emerged as a promising material for quantum applications, due in part to its optical and mechanical properties and in part to its addressable quantum defects. I will discuss the strain coupling of NV centers to individual phonon modes in diamond nanostructures and describe applications of this coupling mechanism for actuation (lasing) and ground state cooling of diamond nanoresonators. Further I will show how the combination of these schemes leads to a novel type of PT-symmetry breaking phase transition in coupled resonator arrays with engineered loss and gain.
17:30	**525**	**Anharmonic magnetic response of magnetic nanoparticles detected by atomic rf magnetometry** *Simone Colombo, Victor Lebedev, Zoran D. Gruijc, Vladimir Dolgovskiy, Antoine Weis* *Department of Physics, University of Fribourg, Chemin du Musée 3, CH-1700 Fribourg* We detect the AC-response of harmonically-excited magnetic nanopaticles (MNP) with a laser-pumped atomic rf magnetometer (ARFM). The ARFM operation in an Mx-magnetometer regime was examined, where the overtone fields produced by the MNPs' nonlinearity act as spin-depolarizing rf-fields. The rf-resonance amplitudes are proportional to specific MNP field harmonics. However, multiphoton rf-transitions induced by the excitation field strongly perturb the magnetometer readout. In order to avoid multiphoton perturbations we studied the ARFM performance in the self-oscillating mode, where bandwidth is limited only by the photodetection's speed. This allows the sensitive (50 pT/$Hz^{1/2}$) and broadband (10 kHz) detection of the anharmonic MNP oscillations.
17:45	**526**	**A hybrid sensor based on nitrogen-vacancy center in diamond and piezomagnetic film for nanoscale stress measurement** *Phani Peddibhotla [1], Benjamin Riedmueller [2], Farzaneh Vaghefikia [1], Liam McGuinness [1], Jianming Cai [3], Martin Plenio [3], Berndt Koslowski [4], Ulrich Herr [5], Fedor Jelezko [1]* *[1] Institute for Quantum Optics, University of Ulm, Albert Einstein Allee 11, DE-89081 Ulm* *[2] Institute for Micro- and Nanomaterials, University of Ulm, Albert Einstein Allee 47, DE-89081 Ulm* *[3] Institute for Theoretical Physics, University of Ulm, Albert Einstein Allee 11, DE-89081 Ulm* *[4] Institute for Solid State Physics, University of Ulm, Albert Einstein Allee 11, DE-89081 Ulm* *[5] Institute for Micro- and Nanomaterials, University of Ulm, Albert Einstein Allee 47, DE-89081 Ulm* We report on the development of a hybrid diamond-piezomagnetic system for the measurement of stress (force) [1]. The hybrid device consists of a thin magnetostrictive film deposited onto the diamond sample containing nitrogen-vacancy (NV) centers. Application of a stress on the thin film results in a change in the stray magnetic field outside the magnetostrictive material. Optical readout of the spin quantum state of the NV center encodes information about the change in the magnetic field thereby resulting in a transduction of force or pressure. [1] J. Cai, F. Jelezko, and M. Plenio, Nat. Commun. 5:4065 (2014).
18:00	**527**	**Silicon-Nitride Integrated Source of Narrowband Entangled Photon-Pairs** *Sven Ramelow [1], Alessandro Farsi [1], Stephane Clemmen [1], Daniel Orquiza [2], Kevin Luke [2], Michal Lipson [2], Alexander Gaeta [1]* *[1] School of Applied and Engineering Physics, Cornell Univ., Clark Hall, 14853 Ithaca, NY, USA* *[2] School of Electrical and Computer Engineering, Cornell Univ., Phillips Hall, 14853 Ithaca, NY, USA* Narrowband entangled photons are essential for future quantum communication networks based on quantum memories and become increasingly relevant for single photon cavity quantum-optomechanics. They have so far been generated with bulk cavity-enhancement or narrow filtering, which entails high complexity and stabilization requirements and thus prohibits real scalability. Using integrated optics based on the CMOS-compatible silicon nitride platform, here we realize an ultra-compact, very-bright entangled pair source with selectable bandwidths down to 30 MHz. Using spontaneous four-

		wave mixing in fully integrated, high-Q microring-resonators we show robust tunability and precise wavelength stabilization and demonstrate high purity and time-bin entanglement of the generated photon pairs.
18:15	**528**	**Thin-disk laser multi-pass amplifier** *Karsten R. F. Schuhmann [1], Aldo Antognini [1], Klaus Stefan Kirch [1], Randolf Pohl [2], Marwan Abdou Ahmed [3], Tomas Graf [3], for the CREMA collaboration* *[1] ETH Zürich, Otto-Stern-Weg 5 , CH-8093 Zürich* *[2] Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, DE-85748 Garching* *[3] IFSW Universität Stuttgart, Pfaffenwaldring 43, DE-70569 Stuttgart* Spectroscopy of 2S-2P transitions in muonic atoms provide a precise determination of nuclear charge radii. For spectroscopy in $\mu^{3,4}He^{+}$ we developed a thin-disk laser delivering pulses of 150 mJ at a pulse duration of 30 ns. Its peculiar requirements are stochastic trigger and short delay time (< 500 ns) between trigger and optical output. One of the most challenging part of the laser system is the multi-pass amplifier, that contrarily to a 4f-design, is insensitive to thermal lens and misalignment effects. The amplifier was running for more than 3 months without the need of realignment. This work is supported by the SNSF grant #200021L_138175.
18:30		
19:15		***Transfer to Dinner***
20:00		***Conference Dinner***

Thursday, 03.09.2015, Room EI 8

Time	ID	IV: Cold Atoms / Matter Waves *Chair: Wolfgang E. Ernst, TU Graz*
14:00	**531**	**Detection of non-locality in a Bose-Einstein condensate** *Baptiste Allard [1], Roman Schmied [1], Matteo Fadel [1], Philipp Treutlein [1], Nicolas Sangouard [1], Jean-Daniel Bancal [2], Valerio Scarani [2]* *[1] Departement Physik, Universität Basel, Klingelbergstrasse, 82, CH-4056 Basel* *[2] Centre for quantum technologies, National University of Singapore, 3 Science Drive 2, SG-11175 Singapore* Measurements performed on quantum systems can exhibit correlations with no classical explanation. These so-called non-local correlations are revealed through the violation of a Bell inequality and form an important resource for quantum technology. While non-locality has been demonstrated in few-particle systems, its role in many-body systems is much less understood. A recent theory paper proposes many-body Bell inequalities relying on single- and two-particle correlations only. Based on this, we introduce and experimentally implement a technique to detect non-locality in spin-squeezed states of a two-component Bose-Einstein condensate. From measurements of first and second moments of the collective atomic spin along several axes, our experiments reveal non-locality in spin-squeezed BECs.
14:15	**532**	**A cold source for matter-wave interferometry with polypeptides** *Philipp Geyer [1], Ugur Sezer [1], Lukas Mairhofer [1], Christian Brand [1], Moritz Hambach [2], Lisa Wörner [1], Jonas Schätti [3], Marcel Mayor [3], Valentin Köhler [3], Markus Arndt [1]* *[1] Faculty of Physics, University of Vienna, Boltzmanngasse 5, AT-1090 Wien* *[2] Imperial College, Centre for Cold Matter, Prince Consort Road, London, UK* *[3] Department of Chemistry, University of Basel, Spitalstrasse 51, CH-4056 Basel* Matter-wave interferometry with photodepletion gratings is proposed to enable new quantum-assisted measurements on complex biomolecular nanoparticles, including polypeptides such as gramicidin, indolicidine or poly-tryptophan. The interferometer is built from three pulsed optical gratings which allow particles to pass at their nodes but deplete the particle beam by ionization or fragmentation of the molecules. The new source uses surface assisted laser desorption and it stabilizes the particles in a cryogenic collision channel. We discuss the relevance of the molecular properties, stability, velocities and photo-detectability with a focus on interference experiments with complex biomolecules.

14:30	**533**	**Observation of a quantum Cheshire Cat in a matter-wave interferometer experiment** *Tobias Denkmayr, Yuji Hasegawa, Stephan Sponar, Hermann Geppert, Hartmut Lemmel, Atominstitut - TU Wien, Stadionallee 2, AT-1020 Wien* A paradoxical phenomenon found within the framework of quantum mechanics is the "quantum Cheshire Cat": If a quantum system is subject to a certain pre- and post selection, it can behave as if a particle and its property are spatially separated. In this talk the first experimental realization of a quantum Cheshire Cat is presented. We sent neutrons through a perfect silicon crystal interferometer and performed weak measurements to probe the location of the particle and its magnetic moment. The experimental results suggest that the system behaves as if the neutrons went through one beam path, while their magnetic moment travelled along the other.
14:45	**534**	**Shaping arbitrary light potentials for matter-wave optics experiments** *Mario Rusev, Mateusz Kotyrba, Michael Keller, Mariusz Semczuk, Anton Zeilinger IQOQI Vienna, University of Vienna, Boltzmanngasse 3, AT-1090 Vienna* For matter-wave experiments with ultracold atoms, we are interested in producing arbitrary light configurations with a spatial light modulator (SLM) via different algorithms (Gerchberg-Saxton, mixed region amplitude freedom (MRAF), etc.) These include variable number of spots, gratings, Laguerre-Gauss beams etc. with adjustable size and relative distance. Such light patterns can be used as a trapping potential or for outcoupling atoms from a Bose-Einstein condensate. Wavefront correction and sources of error and noise have been analyzed and methods for overcoming these technical challenges are presented.
15:00	**535**	**Matter-wave diffraction at the physical limit** *Christian Brand [1], Michele Sclafani [2], Christian Knobloch [1], Yigal Lilach [3], Thomas Juffmann [4], Jani Kotakoski [1], Clemens Mangler [1], Andreas Winter [5], Andrey Turchanin [5], Jannik Meyer [1], Ori Cheshnovsky [6], Markus Arndt [1]* *[1] Faculty of Physics, University of Vienna, Boltzmanngasse 5, AT-1090 Vienna* *[2] ICFO - Institut de Ciences Fotoniques, Av. Carl Friedrich Gauss 3, ES-08860 Castelldefels* *[3] Center of Nanoscience and Nanotechnology, Tel Aviv Univ., Haim Levanon St., IL-69978 Tel Aviv* *[4] Physics Department, Stanford University, 382 Via Pueblo Mall, 94305 Stanford, USA* *[5] Institute of Physical Chemistry, University Jena, Lessingstraße 10, DE-07743 Jena,* *[6] School of Chemisty, Tel-Aviv University, Haim Levanon St., IL-69978 Tel Aviv* The size of particles that can be diffracted at mechanical gratings is limited by the van der Waals interaction between the grating and the matter-wave. In order to increase the accessible mass regime, the thickness of the grating material has to be minimized. Here, we present matter-wave diffraction of organic molecules at gratings milled into several ultra-thin membranes with a thickness down to the physical limit, a single layer of graphene. From the population of high diffraction orders we deduce a strong decrease in the van der Waals interaction, which might pave the way for new quantum experiments.
15:15		
16:30		***Coffee Break***
		V: Mesoscopic and hybrid systems *Chair: Markus Koch, TU Graz*
17:00	**541**	**Suppression of decoherence through spectral hole burning in a hybrid quantum system** *Andreas Angerer, Technical University Vienna, Stadionallee 2, AT-1020 Wien* Coupling nitrogen-vacancy center spins to a superconducting resonator is a prominent example for a strongly coupled cavity QED system. Due to the nature of the NV center spin however large ensembles of this paramagnetic defect are required in order to achieve strong coupling between the cavity mode and the spins. This leads unavoidably to inhomogeneous broadening of the spins, the main source of decoherence in the system. By shaping the spin distribution using spectral hole-burning it is possible to reduce this inhomogeneous broadening in the coupled cavity spin system, increasing the coherence times by more than one order of magnitude.

17:15	**542**	**Sympathetic cooling and self-oscillation in a hybrid atom-membrane system** *Aline Faber, Tobias Kampschulte, Andreas Jöckel, Lucas Beguin, Thomas Karg, Philipp Treutlein, Departement Physik, Universität Basel, Klingelbergstrasse 82, CH-4055 Basel* Hybrid systems combining mechanical oscillators and ultracold atoms provide novel opportunities for cooling, detection and quantum control of mechanical motion. We present our atom-membrane experiment in which laser-cooled atoms in an optical lattices are coupled to the vibrations of a Si_3N_4 membrane. We exploit this coupling to sympathetically cool the membrane from room temperature to 650 ± 330 mK [1]. Under certain experimental conditions the atom-membrane system shows self-oscillations, which could arise e.g. from a time-delay in the coupling. This can drive the system into limit cycle oscillations if the coupling is large. [1] Jöckel, A. et al. Nature Nano. 10, 55-59 (2015)
17:30	**543**	**Alkali Rydberg series on helium droplets: Screening effects of a nanosized helium dielectric** *Wolfgang E. Ernst, Institute of Experimental Physics, TU Graz, Petersgasse 16, AT-8010 Graz Florian Lackner, Chemical Sciences Division, Lawrence Berkeley National Laboratory, 1 Cyclotron Road Mailstop 2-300, 94720 Berkeley, CA, USA* Rydberg series of Li, Rb, and Cs atoms on helium nanodroplets have been studied by resonance enhanced multiphoton ionization and laser induced fluorescence spectroscopy. The spectra are analyzed by using a Rydberg-Ritz approach. The dependence of the quantum defects on the principal quantum number within a Rydberg series provides insight into the interaction between the alkali valence electron and the superfluid helium droplet. For high excitations, screening of the valence electron from the alkali atom core by the helium droplet is observed. For lower states, the screening effect decreases and the quantum defects lie closer to free atom values.
17:45	**544**	**Cavity-assisted manipulation of freely rotating silicon nanorods in high vacuum** *Stefan Kuhn [1], Peter Asenbaum [1], Alon Kosloff [2], Michele Sclafani [1], Benjamin A. Stickler [3], Stefan Nimmrichter [3], Klaus Hornberger [3], Ori Cheshnovsky [2], Fernando Patolsky [2], Markus Arndt [1] [1] Faculty of Physics, University of Vienna, Boltzmanngasse 5, AT-1090 Vienna [2] School of Chemistry, Tel Aviv University, IL-69978 Ramat-Aviv [3] Faculty of Physics, University of Duisburg-Essen, Lotharstraße 1, DE-47048 Duisburg* We present experimental studies of the dynamics of tailored silicon nanorods flying through an optical resonator in high vacuum [1]. Their scattered light allows us to track the rotational and translational motion of each particle in real time. We observe 1D trapping of the rods' center of mass motion as well as optical torques. Our results will be beneficial for improving cooling schemes for silicon nanoparticles in transit through an optical cavity [2] and they represent a first step towards realising torsional optomechanics. [1] S. Kuhn, et al., In preparation; [2] P. Asenbaum, et al. Nature Communications 4, 2743 (2013)
18:00	**545**	**Spectral Hole Burning for Long Coherence Times in Hybrid Quantum Systems** *Stefan Putz [1], Andreas Angerer [1], Ralph Glattauer [1], Dmitry Krimer [2], Stefan Rotter [2], Jörg Schmiedmayer [1], Johannes Majer [1] [1] TU Wien, Stadionallee 2, AT-1020 Wien ; [2] TU Wien, Wiedner Hauptstraße 4, AT-1020 Wien* Spin ensemble quantum memories could find their applications in communication and computation technolofies as recent experiments have shown promising progress. The existence of long lived dark states has been shown in experiments employing strong coupling between cavity and spins on the single photon level. Here we study how such dark states can be engineered in a hybrid quantum system consisting of a superconducting cavity strongly coupled to an ensemble of nitrogen vacancy centers in diamond. This approach allows us to improve the coherence time of the strongly coupled system by a factor of twenty without any refocusing techniques.

18:15	546	**Spectral engineering in hybrid quantum systems with collectively coupled spin ensembles** *Dmitry Krimer [1], Benedikt Hartl [1], Matthias Zens [1], Stefan Putz [2], Johannes Majer [2], Stefan Rotter [1]* *[1] Institute for Theoretical Physics, TU Wien, Wiedner-Hauptstraße 8-10/136, AT-1040 Vienna* *[2] Vienna Center for Quantum Science and Technology, Atominstitut, Stadionallee 2, AT-1020 Vienna* Over the past decade various setups in cavity quantum electrodynamics have been studied in terms of their potential for future technologies involving the storage and processing of quantum information. Among different hybrid quantum systems, the ones based on spin ensembles coupled to superconducting microwave cavities have recently attracted much attention. Whereas it is nowadays possible to reach the regime of strong collective coupling between a cavity and a spin ensemble, such hybrid quantum systems still suffer from a significant degree of decoherence resulting from the inhomogeneous broadening inherent in the ensemble. We could recently show that this strongly restrictive drawback can be overcome simply by burning two narrow spectral holes in the spin spectral density at judiciously chosen frequencies. Using this procedure we find an increase of the coherence time by more than an order of magnitude as compared to the case without hole burning. Furthermore, we demonstrate that engineering the spin spectral density to acquire a comb-like structure leads to coherent revival dynamics with exciting potential for the processing of quantum information.
18:30		***END***
19:45		***Public Lecture***

ID	ATOMIC PHYSICS AND QUANTUM OPTICS POSTER
561	**Characterization of relaxation times in a buffer-gas Rb vapor cell for high-performance Rb atomic clocks** *Mohammadreza Gharavipour, Songbai Kang, Florian Gruet, Christoph Affolderbach, Gaetano Mileti* *Dep. Physics, University of Neuchâtel, Lab. Temps-Fréquence, Avenue de Bellevaux 51, CH-2000 Neuchâtel* We are developing a compact Rb atomic clock based on pulsed optical pumping in the Ramsey scheme, that currently achieves a short-term clock stability of $2.1\times10^{-13}\ \tau^{-1/2}$ [1]. Here we study atomic relaxation times in the ≈ 25 mm diameter Rb cell, that are a limiting factor for the clock's short-term stability. The Franzen method of evolution in the dark is used to measure the population relaxation time T1. Spin-echo-type experiments allow removing dephasing effects due to residual inhomogeneities of the magnetic field inside the Rb vapor cell, and yield a coherence relaxation time T2 ≈ 3 ms, consistent with theoretical expectations. [1] S. Kang et al., J. Appl. Phys. 117, 104510 (2015).
562	**Cavity cooling nanoparticles** *James Millen, Stefan Kuhn, Markus Arndt* *Vienna Centre for Quantum Science & Technology, University of Vienna, Boltzmanngasse 5, AT-1090 Vienna* The prospect of being able to control nanoscale objects on the quantum level is of fundamental (testing the mass limits of quantum physics, investigating the role of gravity) and technological (precision force sensing, signal transduction) interest. This talk will outline experimental progress in using optical cavities to cool and manipulate various nanoparticles, such as spheres, rods and viruses. We see great reductions in the centre of mass temperature of these large objects, and control over their rotational dynamics.
563	**Coulomb explosion of multiply charged helium-nano-droplets** *Lorenz Kranabetter, Paul Scheier, Michael Renzler* *Insitute of Ion Physics and Applied Physics, Technikerstraße 25/3, AT-6020 Innsbruck* The contribution is about the change in the size distribution of charged super_uid helium droplets at high ionization energies. An experiment was designed where charged helium droplets are selected as a function of their kinetic energy by means of an electrostatic sector field. Droplets that passed this sector field differ from the log-normal-distribution of droplets created by a cluster source. Instead a narrow Gaussian distribution has been observed. Delayed decays of these mass-selected charged helium droplets can be analyzed by a subsequent sector field. The results of those measurements support the hypothesis of Coulomb explosion of multiply charged helium droplets.

564	**Contribution of parametric amplification of x-rays in high harmonic generation** *Jozsef Seres [1], David Roca [2], Enikoe Seres [1], Carles Serrat [2]* *[1] Atominstitut, Technische Universität Wien, Stadionalle 2, AT-1020 Vienna* *[2] Universitat Politecnica de Catalunya, Colom 11, ES-08222 Terrassa (Barcelona)* We demonstrate theoretically that coherent nonlinear forward scattering [1] is responsible for the parametric amplification (XPA) [2] of the attosecond pulse-trains in gases. We conclude that XPA can be most efficiently observed by using atoms with high ionization potential [3] and that the nonlinear amplification is robust at high photon energies where HHG is not efficient. We present supporting experimental results in wide spectral range from 40 eV up to 1 keV. [1] C. Serrat, Phys. Rev. Lett. 111,133902 (2013); [2] J. Seres et al., Sci. Rep. 4,4234 (2014); [3] C. Serrat et al., Optics Express 23,4867 (2015)
565	**Ultracold atoms on a superconducting atomchip** *Fritz Diorico, Stefan Minniberger, Jörg Schmiedmayer, Atominsitut TU Wien, Stadionallee 2, AT-1020 Vienna* We present the realization of a robust magnetic transport scheme to bring 3 x 10^8 ultracold ^{87}Rb atoms into a cryostat. The sequence starts with standard laser cooling and trapping of ^{87}Rb atoms, transporting first horizontally and then vertically through the radiation shields into a cryostat by a series of normal- and superconducting magnetic coils. About 3 x 10^6 at 30 μK are subsequently held in a superconducting atomchip. The atomchip is made of a Niobium Z structure, 100 microns wide and 2 mm long. The experiment paves the way for probing superconducting surfaces with ultracold atoms as well as hybrid quantum systems.
566	**On Violating Local Realism with Bell's Inequality** *Marissa Giustina [1], Anton Zeilinger [1], Johannes Kofler [2]* *[1] IQOQI/UniWien, Boltzmanng. 3, AT-1090 Wien* *[2] MPQ Garching, Hans-Kopfermannstraße 1, DE-85748 Garching* Local Realism (LR) is a worldview in which measurement outcomes are probabilistically defined prior to measurement and no physical influence can travel faster than lightspeed. Bell's inequality is an experimental tool for explicitly demonstrating behavior that violates LR. Although a number of experiments have violated Bell's Inequality, a true test of LR has tighter constraints: the nonlocal behavior must be demonstrated in such a way that no LR theory can take advantage of implicit experimental assumptions to explain the outcome. We overview the most relevant concerns and constraints for testing local realism and discuss progress to date on such an experiment using photons.
567	**Adaptive multifrequency light collection** **by self-ordered mobile scatterers in optical resonators** *Valentin Torggler, Helmut Ritsch* *Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 21/3, AT-6020 Innsbruck* Photons carry momentum, and thus their scattering not only modifies light propagation but at the same time induces forces on particles. Confining mobile scatterers and light in a closed volume thus generates a complex coupled nonlinear dynamics. As a striking example, one finds a phase transition from random order to a crystalline structure if particles within a resonator are illuminated by a sufficiently strong laser. Here, we generalize the self-ordering dynamics to several illumination colors and cavity modes. In this enlarged model, particles adapt dynamically to current illumination conditions to ensure maximal simultaneous scattering of all frequencies into the resonator as a sort of self-optimizing light collection system.
568	**Photon Diagnostics at SwissFEL** *Pavle Juranic, Luc Patthey, Jens Rehanek, Ishkhan Gorgisyan, Rasumis Ischebeck, Volker Schlott,* *Rafael Abela, Christian David* *Paul Scherrer Institute, CH-5232 Villigen* The upcoming SwissFEL facility will feature a photon diagnostic suite to fulfill the needs of both the machine operators and the experimenters. This contribution presents the devices and methods that will be used as online diagnostics at SwissFEL, measuring the intensity, position, spectrum, pulse length, and arrival (relative to a pump laser) of the FEL beam. The presentation also discusses the choices, methods, and techniques used to ensure their reliability and endurance over longer periods of time. New devices developed at PSI for some of these types of measurements, like the Photon Arrival and Length Monitor

569	**Testing the foundations of quantum mechanics with multi-path interferometers** *Thomas Kauten, Robert Keil, Thomas Kaufmann, Benedikt Pressl, Gregor Weihs* *Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25, AT-6020 Innsbruck* Born's rule, one fundamental axiom of quantum mechanics, states that the probability density equates the squared magnitude of the wavefunction which implies absence of higher-order interference. In order to test against such higher-order interferences with high precision, we have constructed a very stable optical five-path interferometer with individually controllable phases and individual shutters for the five beams. Our experimental results – compensated for systematic effects such as detector nonlinearities – allow us to put a new and reduced upper bound on any hypothetical higher-order interference, which is at least four orders of magnitude smaller than the expected pairwise interference.
570	**Resonance tuning with asymmetric metamaterials** *Moritz Wenclawiak, Jasmin Karaman, Christian Hartl, Karl Unterrainer, Juraj Darmo* *Institut für Photonik, TU Wien, Gußhausstr. 27-29, AT-1040 Wien* In this contribution we present the response of artificially built metamaterial structures in the THz regime which can be used to gain control over transmission and reflection properties. The investigated metamaterials consist of L- and S-shaped structures with introduced asymmetries obtained by changing the geometric ratio of their arms. The transmission spectra are experimentally measured and the effect of the changed geometry on the resonant frequency and coupling strength is determined. We will use this structure to perform strong coupling experiments in which the developed metamaterial interacts with intersubband transitions in heterostructures.
571	**Coherent manipulation of non-classical motional states** *Sandrine van Frank [1], Robert Bücker [2],* *Tarik Berrada [1], Marie Bonneau [1], Thorsten Schumm [1], Jörg Schmiedmayer [1]* *[1] Atominstitut, TU Wien, Stadionallee 2, AT-1020 Wien* *[2] Struktur und Dynamik der Materie, Max-Planck-Institut, Luruper Chaussee 149, DE-22761 Hamburg* We developed a scheme of coherent control over the motional states of a one-dimensional Bose-Einstein quasi-condensate. Using an atom chip to trap Rubidium atoms and optimal control methods, we excite different transverse motional states of a quasi-condensate and create superpositions of them. In a series of experiments, we implemented a Ramsey interferometer based on these collective vibrational states in the trap. We are currently investigating the specificities of this motional state superpositions, in particular the effect of interactions and decay mechanisms.
572	**Quantum Experiments at Space Scale** *Thomas Scheidl, Anton Zeilinger* *Institut für Quantenoptik und Quanteninformation, Boltzmanngasse 3, AT-1090 Wien* In order to experimentally test the limits of quantum theory and to eventually establish a worldwide quantum communication network, it is important to significantly expand the distances for distributing quantum systems beyond the capabilities of terrestrial experiments. In this respect, one approach, which we tackle in a current project in collaboration with the Chinese Academy of Sciences, is using free-space links involving satellites. The goal is to perform quantum communication experiments in a down-link scenario from a low-earth-orbit satellite to optical ground stations in China and Europe. The main features and the current status of the project will be presented.
573	**Quantum Imaging with undetected photons** *Gabriela Barreto Lemos [1], Sven Ramelow [1,2], Anton Zeilinger [1],* *Garrett Cole [3], Radek Lapkiewicz [1], Victoria Borish [1]* *[1] IQOQI - Vienna, Boltzmanngasse 3, AT-1090 Wien* *[2] Cornell University* *[3] Physics Institute, University of Vienna, Boltzmanngasse 5, AT-1090 Wien* We introduce a novel quantum imaging concept using SPDC. The photons that illuminate the imaged object are never detected, while we obtain images exclusively with the sister photons that do not interact with the object. Our experiment is fundamentally different from previous quantum imaging techniques such as interaction-free imaging or ghost imaging, because now the photons used to illuminate the object do not have to be detected at all and no coincidence detection is necessary. This enables the probe wavelength to be chosen in a range for which suitable detectors are not not commercially available.

574	**Rb-based Stabilized Laser at 1572 nm for CO_2 monitoring** *William Moreno, Florian Grüt, Renaud Matthey, Gaetano Mileti* *Institue de Physique, Université de Neuchâtel, Av. Bellevaux 51, CH-2000 Neuchâtel* A frequency stabilized optical frequency comb (OFC) spanning over 40 nm in the 1.55 mm wavelength region is generated using a DFB laser diode emitting at 1560 nm and an electro-optical modulator. After frequency doubling, the DFB laser is stabilized onto an Rb transition at 780 nm. A second DFB laser, operating at 1572 nm corresponding to a CO_2 absorption wavelength is then offset-locked to one OFC's mode. A frequency stability below 30 kHz for integration times between 30 and 8000 seconds has been demonstrated at 1572 nm. Efforts are being done to improve the short-term stability.
575	**A VUV frequency comb for high-precision spectroscopy of an optical nuclear transition of Thorium-229** *Georg Winkler, Jakob Fellinger, Jozsef Seres, Enikoe Seres, Thorsten Schumm* *Atominstitut, Technische Universität Wien, Stadionallee 2, AT-1020 Wien* A tabletop VUV frequency comb source around 160 nm is demonstrated, implemented by generating the 5th harmonic of a femtosecond Ti:Sa oscillator output via cavity-enhanced high-harmonic generation (HHG) in a Xenon gas jet. A unique 3D-resonator configuration to minimize dispersion and aberration effects is discussed, as well as design considerations for mechanical stability, cavity locking and efficient outcoupling of the VUV radiation. The setup will be used for high-precision spectroscopy of a nuclear optical transition (from a low-energy isomer state) of Th-229 expected around 7.8 eV.
576	**Quantum Interference and the Degree of Polarization of a Light Beam** *Mayukh Lahiri [1], Armin Hochrainer [1], Gabriela Lemos [2], Radek Lapkiewicz [1], Anton Zeilinger [2]* *[1] VCQ, Faculty of Physics, University of Vienna, Boltzmanngasse 5, AT-1090 Vienna* *[2] IQOQI, and VCQ, Faculty of Physics, University of Vienna, Boltzmanngasse 3, AT-1090 Vienna* The quantum mechanical interpretation of single-photon interference arises from the concept of wave-particle duality. If a photon is sent into a two-path interferometer and the interferometric path information is fully available, no interference occurs. On the other hand, perfect interference occurs only when no path information is available. We show that the interferometric path information can play a key role in determining the polarization properties of a photon beam emerging from the output of a two-path interferometer. Our experimental results establish that the degree of polarization can be controlled by modulating the interferometric path information.
577	**Violating a multipartite local-realistic inequality with highly-efficient homodyne detection** *William Plick, Damian Markham, Eleni Diamanti, Télécom ParisTech, 23 Avenue d'Italie, FR-75013 Paris* It has long been a goal in quantum optics and quantum information to violate a Bell-type inequality using only homodyne detection. This would greatly ameliorate the detection-efficiency difficulties when using light. However, this objective has been beyond reach due to very small predicted violation values. A recently developed tool in optics is the synchronously-pumped optical parametric oscillator which is capable of efficiently producing massively multipartite entangled states in the continuous variable regime. We investigate whether this device - coupled with an efficient photon-subtraction technique - is sufficient to violated a local-realistic inequality with homodyne detection performed on the output state.
578	**Atomic self-ordering in a ring cavity with counterpropagating pump fields** *Stefan Ostermann, Tobias Grießer, Helmut Ritsch* *Institut für Theoretische Physik, Technikerstraße 21, AT-6020 Innsbruck* The collective dynamics of mobile scatterers and light in optical resonators generates complex behaviour. For strong transverse illumination a phase transition from homogeneous to crystalline particle order appears. In contrast, cold particles inside a single-side pumped ring cavity exhibit an instability towards bunching and collective acceleration called collective atomic recoil lasing (CARL). We demonstrate that by driving two orthogonally polarized counterpropagating modes of a ring resonator one realises both cases within one system. As a function of the two pump intensities the corresponding phase diagram exhibits regions in which either a generalized form of self-ordering towards a travelling density wave with constant centre-of-mass velocity or a CARL instability is formed.

579 **Nanowire quantum dot molecules**

Tobias Huber [1], Ana Predojević [1],Gregor Weihs [1], Milad Koshnegar [2], Hamed Majedi [2], Dan Dalacu [3], Philip Poole [3]
[1] Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25d, AT-6020 Innsbruck
[2] Institute for Quantum Computing, University of Waterloo, 200 University Ave. West, CA-Waterloo N2L 3G1
[3] National Research Council of Canada, 1200 Montreal Road, CA-Ottawa K1A 0R6

In this work we investigate the emission of InAsP quantum dot molecules embedded into InP nanowires. The quantum dot molecules consist of two vertically stacked single quantum dots. This design opens unprecedented flexibility and allows for creating more interesting state configurations, compared to a single dot. We perform photon correlation measurements under optical excitation in cryogenic environment and show that the system consists of a quantum dot molecule rather than two single quantum dots.

580 **Towards multiple phase measurements of a single pair of Bose-Einstein condensates**

Mira Maiwöger, Marie Bonneau, Rugway Wu, Marine Pigneur, Sandrine van Frank, Thorsten Schumm, Jörg Schmiedmayer
Atominstitut, TU Wien, Stadionallee 2, AT-1020 Wien

We propose to experimentally investigate the quantum back-action of phase measurements for a pair of independent Bose-Einstein condensates. To observe how a relative phase is created by the measurement, a Raman laser system has been prepared for pulsed output coupling from clouds of ultracold atoms in radio-frequency dressed double-well potentials on an atomchip.

581 **Swiss made Positrons and Positronium**

Paolo Crivelli, Institute for Particle Physics, ETH Zürich, Otto-Stern-Weg 5, CH-8093 Zürich

We will report on the activities of our Laboratory for Positron and Positronium Physics at ETH Zurich. These include precise spectroscopic studies of the electron-positron bound system called positronium, searches for new Physics, test of fundamental symmetries and application of positron and positronium for investigation of nanoporous materials.

582 **Advances in semiconductor waveguide characterization**

Benedikt Pressl [1], Thomas Günthner [1], Kaisa Laiho [1], Jonas Gessler [2], Sven Höfling [2], Christian Schneider [2], Martin Kamp [2], Gregor Weihs [1]
[1] Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25d, AT-6020 Innsbruck
[2] Technische Physik, Universität Würzburg, Am Hubland, DE-97074 Würzburg

Recently, multimode semiconductor waveguides have been demonstrated to be efficient sources for nonlinear optics [1]. Their classical optical properties, like mode reflectivity, relative excitation, loss and propagation index, are usually assessed through simulations as they are difficult to measure directly. Standard methods, like the fringe contrast method, may fail because of overlapping characteristics of the modes. In this work we show how to use Fourier analysis of the optical transmission spectrum of a semiconductor waveguide to robustly extract modally resolved information. Our results are essential for the engineering and control of these modes for low loss and high conversion efficiency.

[1] A. Helmy et al., Laser Photonics Rev. 5, 272 (2011).

583 **Quantum Interference Fringes Controlled with Non-interfering Photons**

Armin Hochrainer [1], Radek Lapkiewicz [1], Mayukh Lahiri [2], Gabriela Barreto Lemos [1], Victoria Borish [1], Anton Zeilinger [1]
[1] Institute for Quantum Optics and Quantum Information, Vienna, Boltzmanngasse 3, AT-1090 Vienna
[2] Faculty of Physics, University of Vienna, Boltzmanngasse 5, AT-1090 Vienna

We observe interference fringes controlled by a light beam that does not interfere itself. In our experiment, two separate non-linear crystals are illuminated by the same pump laser. Each crystal produces two down-converted beams, signal and idler. Interference fringes are observed in the superposed signal beam due to “induced coherence without induced emission”. In conjunction with the momentum correlation of photons generated in SPDC, this leads to interference fringes, which show strikingly different features than those observed in a traditional interferometer. In particular, the obtained fringes can be characterized by an effective wavelength, which corresponds to a combination of the wavelengths of signal and idler photons.

584	**Coherence and degree of time-bin entanglement from quantum dots** *Max Prilmüller [1], Ana Predojevic [1], Tobias Huber [1], Gregor Weihs [1], Laurin Ostermann [2], Helmut Ritsch [2], Glenn S. Solomon [3]* *[1] Institut für Experimentalphysik, Universität Innsbruck, Tehnikerstraße 25d, AT-6020 Innsbruck* *[2] Institut für Theoretische Physik, Universität Innsbruck, Tehnikerstraße 25d, AT-6020 Innsbruck* *[3] Joint Quantum Inst., NIST, University of Maryland, 100 Bureau Drive, Stop 1070, 20849 Gaithersburg, USA* We report on the generation of time-bin entangled photon pairs from a semiconductor quantum dot via pulsed resonant biexciton generation. Based on theoretical modelling we optimized the duration of the excitation pulse to minimize the laser-induced dephasing and increase the biexciton- to-background single exciton occupation probability. This results in a high degree of entanglement with concurrence of up to 0.78(6) and a 0.88(3) overlap with a maximally entangled state.
585	**Experimental Creation and Verification of Multi-Partite High-Dimensional Entanglement** *Manuel Erhard [1], Mehul Malik [1], Mario Krenn [1], Robert Fickler [1], Marcus Huber [2], Anton Zeilinger [1]* *[1] University of Vienna, Boltzmanngasse 5, AT-1190 Vienna* *[2] Universitat Autonoma de Barcelona, Bellaterra, ES-08193 Barcelona* Recent developments in experimental and theoretical quantum information lead to a new class of entangled states. In our specific scheme we will consider photons as the physical carrier of the high-dimensional state, namely the orbital-angular-momentum (OAM). Necessary and sufficient theoretical conditions will be introduced in the form of an entanglement witness. These witness measurements are then used to verify genuine multi-partite and high-dimensional entanglement experimentally.
586	**InAs/AlSb terahertz quantum cascade laser** *Martin A. Kainz [1], Tobias Zederbauer [2], Martin Brandstetter [1], Michael Krall [1], Sebastian Schönhuber [1], Gottfried Strasser [2], Karl Unterrainer [1]* *[1] Photonics Institute, TU Wien, Gußhausstraße 25-29, AT-1040 Vienna* *[2] Institut für Festkörperelektronik, TU Wien, Floragasse 7, AT-1040 Vienna* We investigate in the material system InAs/AlSb as an active region for a terahertz (THz) quantum cascade laser (QCL). The small effective mass of the well material InAs ($m^* = 0{,}023\ m_0$) compared to standard materials (GaAs/AlGaAs $m^* = 0{,}067\ m_0$) is attractive because it enables a large optical gain coefficient which scales with $m^{*-3/2}$. This will lead to a better temperature performance of the THz-QCL. The active region structure has been grown by molecular beam epitaxy and a double metal waveguide is used.
587	**Fast Production of Correlated He* Atom Pairs** *Michael Keller, Mateusz Kotyrba, Maximilian Ebner, Mario Rusev, Mariusz Semczuk, Anton Zeilinger* *IQOQI Wien / VCQ, Boltzmanngasse 3, AT-1090 Wien* While ultracold-atom experiments that focus on a single-particle level gain more and more attention, many of them require a frequent repetition to obtain good statistics. Stability of experimental parameters and a fast production of the ultracold sample therefore become crucial factors for feasibility. We present our setup to produce large Bose-Einstein condensates of metastable helium in less than 5 seconds. In combination with multiple Raman pulses per BEC, this enables a fast production of collisionally entangled atom pairs, even if collisions rates have to be kept low to allow for identification of individual pairs.
588	**Probing Ultracold Quantum Gases with HBT and higher-order Correlation Measurements** *Rugway Wu, Atominstitut, TU Wien, Stadionallee 2, AT-1020 Wien* The coherence properties of quantum systems as revealed in correlation functions, can be a powerful tool for probing the states of the system measured. A key property of 3-dimensional BECs for instance, is long range coherence, described by the correlation functions of first, second, and higher orders. With metastable helium atoms we perform correlation measurements to high order, demonstrating the possibility to probe quantum gases efficiently in experiments. We have also applied measurements to test the coherence of amplified matter waves, monitor the process of condensate formation following a quench, and reveal transverse condensation of an elongated gas.

589	**Tailoring light transport at the nanoscale**

Tailoring light transport at the nanoscale

Filippo Fratini [1], Eduardo Mascarenhas [2], Laleh Safari [3], Jean-Philippe Poizat [4], Alexia Auffèves [4], Daniel Valente [5], Dario Gerace [6], Marcelo Santos [2]
[1] TU Wien, Stadionallee 2, AT-1020 Vienna
[2] Universidade Federal de Minas Gerais, Av. Antonio Carlos, BR-31270901 Belo Horizonte
[3] IST Austria, Am Campus, AT-3400 Klosterneuburg
[4] Institut NÉEL, rue des Martyrs 25, FR-38042 Grenoble
[5] Universidade Federal de Mato Grosso, Av. Fernando Correa da Costa, BR-78060900 Cuiaba
[6] Università di Pavia, via Bassi 6, IT-27100 Pavia

Optical transport represents a natural route towards fast communications. The progressive miniaturization of devices for information processing calls for the tailoring of light transport at microscopic scales. As electronic diodes have significantly contributed to the electronic revolution in the past century, optical diodes are also expected to be important for achieving reliable optical transport. The ideal optical diode is capable to work at the quantum regime and can be integrated in one-dimensional nanoscale geometries. We here show that a one dimensional wave-guide with two embedded two-level systems represents a valid candidate for such a nanoscale device.

590

General description of quasi-adiabatic dynamical phenomena near exceptional points

Thomas Milburn [1], Jörg Doppler [2], Catherine Holmes [3], Stefano Portolan [4], Stefan Rotter [2], Peter Rabl [1]
[1] Institute of Atomic and Subatomic Physics, Vienna University of Technology, Stadionallee 2, AT-1020 Vienna
[2] Institute for Theoretical Physics, Vienna University of Technology, Wiedner Hauptstr. 8–10, AT-1040 Vienna
[3] School of Mathematics and Physics, University of Queensland, St Lucia, 4072 QLD, Australia
[4] Department of Physics and Astronomy, University of Southampton, Southampton SO17 1BJ, UK

The appearance of exceptional points in the complex spectra of non-Hermitian systems is associated with phenomena that contradict physical intuition. One example of particular interest is the state-exchange process predicted for an adiabatic encircling of an exceptional point. In this work we analyse this and related processes for the generic system of two coupled oscillator modes with loss or gain. We identify a characteristic system evolution consisting of periods of quasi-stationarity interrupted by abrupt non-adiabatic transitions, and we present a qualitative and quantitative description of this switching behaviour by connecting the problem to the phenomenon of stability loss delay.

591

Stationary phases of parity-time-symmetric (phonon) laser arrays

Kosmas Kepesidis, TU Wien, Stadionallee 2, AT-1020 Vienna

In this work we analyze the stationary phases of systems with an underlying parity-time (PT) symmetry and show that nonlinear saturation effects and the presence of noise in real systems result in an unexpected behavior, which differs significantly from the usual dynamical picture. In particular, we discover symmetry-breaking delay, phases with a `weakly' broken PT symmetry and an unconventional transition from a high-noise thermal to a low-amplitude lasing state. As a specific example where all those effects are highly relevant, we focus in our analysis on coupled mechanical resonators with optically induced loss and gain.

592

Applications of the hybrid quantum system consisting of NV-center spin ensembles

Zeliang Xiang, Peter Rabl, Atominstitut, TU Wien, Stadionallee 2, AT-1020 Vienna

Hybrid quantum systems (HQSs) combine two or more physical systems, with the goal of harnessing the advantages and strengths of the different systems in order to better explore new phenomena and potentially bring about novel quantum technologies. Here we explored some promising applications of the HQSs consisting of superconducting circuits and NV-center spin ensembles, such as quantum information transfer and preparation of the spin state. In particular, these hybrid quantum systems can be fabricated on a chip, facilitating their future scalability, which is crucial for building future quantum technologies.