Atomic Physics and Quantum Optics

Thursday, 29.08.2019, Room G 91

<table>
<tr><th>Time</th><th>ID</th><th>Atomic Physics and Quantum Optics I
Chair: Lauri Toikka, Uni Innsbruck</th></tr>
<tr><td>14:45</td><td>401</td><td>Terahertz quantum optics in the time-domain.

Ileana-Cristina Benea-Chelmus
Harvard John A. Paulson School of Engineering and Applied Sciences, Cambridge MA 02138

The field of terahertz (0.1-10 THz) science and technology has had an exotic standing for a long time, due to the lack of performant sources and detectors. In this range, both electronics and optics fail to provide a performant solution. The scope of this work was to initiate experiments in quantum optics at terahertz frequencies, which lead to the exploration of the characteristics of quantum states of light in the time-domain. Using in-house developed ultrasensitive field measurement techniques we measure, for the first time, the field correlation on the electromagnetic vacuum state as a function of time and space.</td></tr>
<tr><td>15:15</td><td>402</td><td>Positronium and Muonium precision spectroscopy:
Measurement of the 1S-2S and excited state hyperfine transitions

Michael Heiss [1], Artem Golovizin [2], Zak Burkley [1], Paolo Crivelli [1]
[1] ETH Zürich, [2] Lebedev Physical Institute

Positronium and Muonium are excellent systems to test bound-state QED theory to high precision. This has motivated numerous precise experiments aimed at measuring the hyperfine splitting and 1S-2S transition of these atoms.
Currently, there is some disagreement with the most recent bound-state QED calculations for the hyperfine splitting in positronium. Our approach to resolve this, PHySES, eliminates several possible sources of systematics present in earlier experiments by a novel experimental design.
Furthermore, measurements of the 1S-2S transition can test bound state QED in the ppb range and determine fundamental constants, e.g., the muon mass.
Here we present current efforts to reach this sensitivity.</td></tr>
<tr><td>15:30</td><td>403</td><td>Spatial hole burning in thin-disk lasers and twisted-mode operation

Karsten Schuhmann [1], Aldo Antognini [1,2], Klaus Kirch [1,2], Miroslaw Marszalek [2], Randolf Pohl [3], Laura Sinkunaite [1], Manuel Zeyen [1], Francois Nez [4]
[1] ETH Zürich, [2] Paul Scherrer Institute, [3] Johannes Gutenberg University Mainz, [4] CNRS

Spatial hole burning prevents single-frequency operation of thin-disk lasers when the thin disk is used as a folding mirror. We present an evaluation of the saturation effects in the disk for disks acting as end-mirrors and as folding-mirrors explaining one of the main obstacles towards single-frequency operation. It is shown that a twisted-mode scheme based on a multi-order quarter-wave plate combined with a polarizer provides an almost complete suppression of spatial hole burning and creates an additional wavelength selectivity that enforces efficient single-frequency operation. We want to discuss the disadvantages and benefits of spatial hole burning in different laser systems.</td></tr>
<tr><td>15:45</td><td>404</td><td>Direct field correlation measurement on the electromagnetic ground state

Francesca Fabiana Settembrini, Ileana-Cristina Benea-Chelmus, Giacomo Scalari, Jérôme Faist
ETH Zürich, Institute for Quantum Electronics

The ground state of electromagnetic radiation is characterized by the presence of fluctuating zero-point electric fields. A direct method to characterize their spectral composition is still missing. In this work, we present the first direct electric field correlation measurement on the electromagnetic vacuum state at terahertz frequencies. It presents a peak value of 6.20×10^{-2} volts squared per square meter at zero time delay. Its measurement has been performed using a combination of electro-optic detection and ultrashort pulses. The spatial dependence of the field coherence has been investigated, together with the influence of the probed space-time volume on the detection bandwidth. We also provide a model for the quantitative prediction of the experimental result.</td></tr>
</table>

16:00	**405**	**Phase transition in the dynamical response of driven-dissipative light-matter systems** *Matteo Soriente, Oded Zilberberg, Ramasubramanian Chitra, ETH Zürich* We study a paradigmatic quantum-optical model, where a collection of two-level systems interact with both quadratures of a cavity mode. The closed system exhibits rich physics, including discrete and continuous symmetry-breaking phase transitions. Exploring the dynamical response, we find an additional transition manifesting in the system's frequency response. Particle-hole like processes exchange due to a soft mode gap closing. In the driven-dissipative version of this model the phase diagram is profoundly altered. Novel regions of coexistence of phases appear at the expense of broken continuous symmetry transitions. Using Keldysh formalism, we show that the phase transition in frequency domain survives and the system shows signature of a Fano resonance. Our predictions pave the way for experimental observation of this effect.
16:15	**406**	**Quantum dynamics of a harmonic oscillator in a bath of two-level atoms** *Katja Kustura, Carlos Gonzalez-Ballestero, Oriol Romero-Isart* *Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences &* *Institute for Theoretical Physics, University of Innsbruck* Low-temperature decoherence in many quantum systems, such as magnons or NV centers, is attributed to the interaction with the atomic impurities in the sample. We propose a model describing effective dynamics of a harmonic oscillator in the presence of impurities based on master equation formalism, to model such behaviour. Impurities are modelled as a bath of two-level atoms, which is a rather unconventional scenario, since in the context of quantum optics the bath is usually bosonic. We use our model to study the dependence of the Kittel magnonic mode linewidth in a Yittrium-iron-garnet sphere in a ferromagnetic resonance experiment, where the driving field affects not only the magnon, but also the two-level atoms, and compare our results with recent experiments.
16:30		***Coffee Break***
		Atomic Physics and Quantum Optics II *Chair: Ileana-Cristina Benea-Chelmus, Harvard University*
17:00	**411**	**Ultra-coherent micro-mechanical resonators for quantum information processing at room temperature** *Amir H. Ghadimi [1,2], Sergey Fedorov [1], Nils Johan Engelsen [1], Mohammad Bereyhi [1],* *R. Schilling [1], D. J. Wilson [3], Tobias J. Kippenberg [1]* *[1] EPFL, [2] CSEM, Neuchâtel, [3] The University of Arizona, Tucson, USA* Elastic strain engineering utilizes stress to realize unusual material properties. Here we show that geometric strain engineering combined with soft-clamping can produce unprecedentedly high quality factor nano-mechanical resonators. Specifically, using a spatially non-uniform phononic crystal pattern, we co-localize the strain and flexural motion of a SiN nano-beam, while increasing the former to near the yield strength. This combined approach produces string-like resonators with room-temperature $Q \times f > 10^{15}$ Hz, far exceeding previous values for a mechanical oscillator of any kind. At room temperature, this device can achieve force sensitivity of ~1 $aN/\sqrt{Hz}$, performs hundreds of quantum coherent cycles, and attain $Q > 10^9$ at megahertz frequencies.
17:30	~~412~~	cancelled

17:45	**413**	**Spin drag in a one-dimensional quantum wire** *Anne-Maria Visuri, Thierry Giamarchi* *Department of Quantum Matter Physics, University of Geneva* When particles with opposite spin scatter, momentum is transferred from one spin species to the other causing a spin drag - a friction between the relative motion of the two spin components. This phenomenon is relevant for spintronics devices, and has also been explored in experiments with ultracold atoms. Motivated by recent experiments [1,2], we consider spin drag in a one-dimensional quantum wire. For attractive interactions, a nonzero spin drag is caused by pairing of fermions with opposite spin. We investigate analytically and numerically the possibility of spin drag when interactions are repulsive and the ground state is a spin density wave. 1 S. Krinner et al., PNAS 113, 8144 (2016) 2 M. Lebrat et al., PRX 8, 011053 (2018)
18:00	**414**	**Non-Abelian Majorana fermions in topological s-wave Fermi superfluids** *Lauri Toikka, University of Innsbruck* By solving the Bogoliubov–de Gennes equations analytically, we derive the fermionic zero-modes satisfying the Majorana property that exist in vortices of a two-dimensional s-wave Fermi superfluid with spin-orbit coupling and Zeeman spin-splitting. The Majorana zero-mode becomes normalisable and exponentially localised to the vicinity of the vortex core when the superfluid is topologically non-trivial. We calculate the energy splitting due to Majorana hybridisation and identify that the s-wave Majorana vortices obey non-Abelian statistics.
18:15	**415**	**Diverging exchange force for ultracold fermionic atoms** *Christian Schilling, University of Oxford, Rolf Schilling, University of Mainz* The Pauli exclusion principle $0 \leq n_k \leq 1$ is a kinematical constraint on fermionic occupation numbers which strongly shapes fermionic quantum systems on all length scales. We demonstrate that this fundamental restriction can also be interpreted dynamically: the fermionic exchange symmetry manifests itself in the one-fermion picture in the form of an “exchange force” which repulsively diverges on the boundary of the allowed region, preventing fermionic occupation numbers n_k from leaving their domain $0 \leq n_k \leq 1$. Moreover, for translationally invariant one-band lattice models, we exploit the knowledge of the natural orbitals (momentum states) and discover the form of the exact one-particle reduced density matrix functional $\mathcal{F}(\vec{n})$. Remarkably, $\mathcal{F}(\vec{n})$ turns out to be strongly shaped by Pauli’s exclusion principle.
18:30		***END***
19:00		***Transfer to Dinner***
19:30		***Conference Dinner***