A 42: Ultracold atoms and molecules I (with Q)

Time: Thursday 14:00–15:30 Location: DO26 208

A 42.1 Thu 14:00 DO26 208

Nonlinear spectroscopy of trapped ions — •Manuel Gessner[1,2], Frank Schlawin[1,3], Hartmut Häffner[2], Shaul Mukamel[3], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Department of Physics, University of California, Berkeley, California 94720, USA — [3]Department of Chemistry, University of California, Irvine, California 92697, USA

Nonlinear multidimensional spectroscopy is a powerful tool to probe non-equilibrium phenomena of complex quantum systems. It has been successfully implemented in systems ranging from nuclear magnetic resonance to molecular aggregates. In this talk we present experimentally feasible methods to obtain multidimensional spectra for the electronic and vibrational degree of freedom of trapped ion systems. The ability to address single ions provides unprecedented possibilities for the design of multidimensional signals. The obtained spectra can be used to study quantum transport and different environmental effects.

A 42.2 Thu 14:15 DO26 208

Atom-light Quantum Interface Based on Nanofiber Traps — •Eva Bookjans, Jean-Baptiste Béguin, Stefan L. Christensen, Heidi L. Sørensen, Jörg H. Müller, Jürgen Appel, and Eugene S. Polzik — Niels Bohr Institute, Copenhagen University, Denmark

We report on our experimental progress towards coupling ultra-cold atoms to a tapered optical nanofiber with a subwavelength diameter. The strong coupling between the guided light mode of a tapered optical nanofiber and atoms close to the fiber surface make it an ideal system not only for trapping, manipulating, probing, and detecting atoms but also for interfacing distant quantum systems. Laser-cooled Cesium atoms are trapped in a one-dimensional optical lattice potential along the fiber, which is created by the evanescent field of a far red-detuned standing wave (1064 nm) and far blue-detuned (780 nm) light [1]. We will present a dispersive dual-color interferometric probing scheme, which we will implement in order to perform projection noise limited quantum-non demolition (QND) measurements of the quantum state of the trapped Cesium atoms [2,3]. The ultimate objective of the presented research is to take advantage of the unique properties of an atom-nanofiber trap and to engineer and characterize nontrivial quantum states in few atom ensembles using QND coupling to light and photon counting measurements.

[1] E. Vetsch *et al.*, Phys. Rev. Lett. **104**, 203603 (2010)
[2] J. Appel *et al.*, PNAS **106**, 10960 (2009)
[3] J. Lodewyck *et al.*, Phys. Rev. A **79**, 061401 (2009)

A 42.3 Thu 14:30 DO26 208

3D Imaging of Cavity Vacuum with Single Atoms Localized by a Nanohole Aperture — •Moonjoo Lee[1,2], Junki Kim[2], Wontaek Seo[2], Hyun-Gue Hong[2], Younghoon Song[2], Ramachandra Dasari[3], and Kyungwon An[2] — [1]Institute for Quantum Electronics, ETH Zürich, CH-8093 Zürich, Switzerland — [2]Department of Physics and Astronomy, Seoul National University, Seoul 151-747, Korea — [3]G. R. Harrison Spectroscopy Laboratory, Massachusetts Institute of Technology, Cambridge, MA 02139, U.S.A.

P. A. M. Dirac first introduced zero-point electromagnetic fields in order to explain the origin of atomic spontaneous emission. Vacuum fluctuations associated with the zero-point energy in cavities are now utilized in quantum devices such as single-photon sources, quantum memories, switches and network nodes. Here we present 3D imaging of vacuum fluctuations in a high-Q cavity based on the measurement of position-dependent emission of single atoms. Atomic position localization is achieved by using a nanoscale atomic beam aperture scannable in front of the cavity mode. The 3D structure of the cavity vacuum is reconstructed from the cavity output. The rms amplitude of the vacuum field at the antinode is also measured to be 0.92 ± 0.07 V/cm. The present work utilizing a single atom as a probe for sub-wavelength imaging demonstrates the utility of nanometer-scale technology in cavity quantum electrodynamics.

A 42.4 Thu 14:45 DO26 208

Quantum simulation of nuclear matter with ultracold molecules — •Jordi Mur-Petit — Instituto de Estructura de la Materia IEM-CSIC, Madrid, Spanien

Cold polar molecules have attracted attention in the last years as systems potentially capable of realizing a variety of strongly-correlated phases of condensed matter, from quantum magnetism models [1] to superconductivity [2] and topological phases [3]. In these and similar proposals, attention has been driven to the use of vibrational and rotational degrees of freedom to encode and manipulate quantum information. Here, we propose to use ultracold molecules to quantum-simulate nuclear matter. We discuss how to harness a manifold of rotational and hyperfine states of polar molecules to encode the degrees of freedom required to quantum-simulate nuclear matter, spin and isospin. Then, we consider the use of external fields to control the intermolecular interactions [4] in order to model known properties of the nucleon-nucleon interaction at low energies. This work is a first step in the study of open problems in nuclear physics, from the equation of state of nuclear matter, to the determination of magic numbers of highly asymmetric nuclei [5]. [1] R. Barnett et al., PRL 96, 190401, 2006. [2] A. Gorkov et al., PRL 107, 115301, 2011. [3] J. Levinsen et al., PRA 013603, 2011; S. Manmana et al., PRB 87, 081106R, 2013. [4] A. Micheli et al., Nat. Phys. 2, 341, 2006; T.V. Tscherbul and R.V. Krems, ch. 4 in "Cold Molecules", edited by R. Krems, W. Stwalley and B. Friedrich, CRC Press, 2010; M. Lemeshko et al., Mol. Phys. 111, 1648, 2013. [6] J. Dobaczewski (ed.), J. Phys. G 37, special issue no. 6, 2010.

A 42.5 Thu 15:00 DO26 208

Towards optical Feshbach resonances with ^{40}Ca — •Evgenij Pachomow[1], Max Kahmann[1], Uwe Sterr[1], Fritz Riehle[1], and Eberhard Tiemann[2] — [1]Physikalisch Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig — [2]Institut für Quantenoptik, Welfengarten 1, 30167 Hannover

Alkaline earth metals find applications in various fields of research and technology. Especially due to the narrow singlet-triplet intercombination line, photoassociation (PA) and optical Feshbach resonance (OFR) experiments have been the subject of research in the last decade. Compared to the other alkaline earth metals like strontium and ytterbium, where PA and OFR have already been performed, calcium offers an even narrower intercombination line of $\Gamma/2\pi \approx 374$ Hz, which is supposed to solve loss problems at OFRs. We recently produced a quantum degenerate ^{40}Ca gas using a two stage magneto-optical trap and subsequent forced evaporation cooling in an optical dipole trap. The interaction in the gas depends on the scattering length, which we plan to tune using the OFR. As a first step in the two molecular potentials c ($\Omega = 0+$) and a ($\Omega = 1$) correlating to the ^{3}P+^{1}S asymptote the six weakest bound photoassociation resonances were measured. Based on this data set these molecular potentials were fitted using a coupled channel model. On the basis of the experimentally observed spectra and the coupled channel model we investigate the feasibility of OFRs and their corresponding losses.

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A 42.6 Thu 15:15 DO26 208

En route to quantum many-body physics with ultracold polar molecules - 23Na40K Feshbach molecules and beyond. — •Nikolaus Buchheim, Zhenkai Lu, Tobias Schneider, Immanuel Bloch, and Christoph Gohle — Max-Planck-Institut für Quantenoptik, Garching, Germany

Ultra cold quantum gases with long-range dipolar interaction promise exciting new possibilities for quantum simulation of strongly interacting many-body systems. New classes of many-body phases (like super solids and stripe phases) are on the horizon and ferroelectric phases of highly polarizable systems are expected [1, 2].

The known route for creating polar molecules from laser-cooled alkaline atoms [3] involves the association of pairs of unbound atoms to weakly bound molecules (Feshbach molecules) using a magnetic field controlled Feshbach type scattering resonance. This is followed by a stimulated Raman adiabatic passage (STIRAP) to the rovibrational groundstate. We report on spectroscopic studies on a near-degenerate 23Na40K mixture along the lines of and expanding on [4].

[1] G. Pupillo et al. arXiv: 0805.1896 (2008).
[2] M. Iskin et al. Phys. Rev. Lett. 99, 110402 (2007).
[3] K.-K. Ni et al. Science 322, 231 (2008).
[4] C.-H. Wu et al. Phys. Rev. Lett. 109, 085301 (2012).