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Poster Abstracts

Poster Session I: Monday, September 12, 20:45-22:00

I.1	*BEC and guided atom optics in optical micro-potentials*	6
I.2	*Bosonic and fermion mixtures of metastable neon and methods to control their collisions*	6
I.3	*Magnetic resonances in quantum degenerate helium*	6
I.4	*Density and spin fluctuations in trapped Fermi gases*	7
I.5	*Crystalline phase for one-dimensional ultra-cold atomic bosons*	7
I.6	*A quantum degenerate mixture of Rb and Cs*	7
I.7	*Non-equilibrium dissipative dynamics and heating of cold atoms in optical lattices*	7
I.8	*Adiabatic quenches of quantum critical systems*	8
I.9	*Photoemission Spectroscopy in an Ultracold Fermi Gas: Investigating the Effects of Density Inhomogeneity*	8
I.10	*Exactly solvable models and ultracold Fermi gases*	8
I.11	*Strain and Dirac equations in optical lattices*	9
I.12	*Self-consistent number-conserving dynamics in a driven Bose-Einstein condensate*	9
I.13	*BCS-BEC of ultracold fermions in the honeycomb lattice*	9
I.14	*How to BEC without Laser Cooling? - Loading a Conservative Trap from an Atomic Beam*	10
I.15	*An electron microscope for a gas of ultracold bosons*	10
I.16	*A Magnetic Lattice for Ultracold Quantum Gases*	10
I.17	*Spin-Asymmetric Josephson Effect, and Speed of Sound in the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) State*	11
I.18	*Sub-Poissonian fluctuations in a 1D Bose gas: from quantum quasi-condensate to the strongly interacting regime*	11
I.19	*Proximity effects in ultracold bosons*	11
I.20	*Probing Ultracold Atoms in Optical Lattices with Light Scattering*	12
I.21	*Textures of spin-orbit coupled F=2 spinor Bose-Einstein condensates*	12
I.22	*Localization from quantum interference in one-dimensional disordered potentials*	12
I.23	*Probing the Equation of State of a Strongly Interacting Bose Gas*	12
I.24	*Quantum Atom Optics at work*	13
I.25	*Microwave-Induced Feshbach Resonances*	13
I.26	*Multi-path Interferometer on Atom Chip*	13
I.27	*Correlated phases of bosons in tilted, frustrated lattices*	14
I.28	*Interferometry with BEC in extended free fall*	14
I.29	*Mass-imbalanced atomic mixtures in one-dimensional optical lattices*	14
I.30	*Confinement-induced resonances revisited*	15
I.31	*Spinor and polar lattice gases*	15
I.32	*Quantum Dynamics and Thermalization*	15
I.33	*Strontium quantum gases*	15
I.34	*Beyond Mean-Field Effects on the Critical Temperature of a Trapped Bose Gas*	16
I.35	*Dynamics and decoherence of two cold bosons in a one-dimensional harmonic trap*	16
I.36	*Collective oscillations in dipolar gases*	16

I.37	*Quantum degenerate mixtures of alkali and alkaline-earth-like atoms*	16
I.38	*The FFLO state and its expansion dynamics in lattices*	17
I.39	*Quantum metrology with ultracold atoms on a chip*	17
I.40	*Density functional theory for ultracold atomic gases*	18
I.41	*Shortcuts to adiabaticity for trapped ultracold gases*	18
I.42	*Chiral superfluidity in higher bands of an optical lattice*	18
I.43	*Inter-band coupling induced novel condensates in a double-well lattice*	18

Poster Session II: Tuesday, September 13, 20:45-22:00

II.1	*Disordered spin-1 Bose-Hubbard model*	19
II.2	*Long coherence time due to spin self-rephasing in an optical trap*	19
II.3	*Bose correlated states from gauge fields*	19
II.4	*Spin diffusion in Fermi gases*	19
II.5	*Embedding a single quantum bit in an ultra-cold Fermi sea*	20
II.6	*The Hyperfine Molecular Hubbard Hamiltonian*	20
II.7	*Dynamical instability of a spin spiral in an interacting Fermi gas as a probe of the Stoner transition*	20
II.8	*Non-equilibrium flows and superfluid turbulence in dilute gas Bose-Einstein condensates*	21
II.9	*Probing magnetic order in ultracold lattice gases*	21
II.10	*s-Wave Interaction in a Two-Species Fermi-Fermi Mixture at a Narrow Feshbach Resonance*	21
II.11	*Topologically protected Majorana Edge States from Dissipation*	22
II.12	*Frustrated quantum antiferromagnetism with spinless bosons*	22
II.13	*Probing an ultracold atomic crystal with matter waves*	22
II.14	*BCS-BEC crossover in a 2D Fermi gas*	23
II.15	*Ultracold fermions in optical lattices with engineered topology*	23
II.16	*Two dimensional bi-chromatic optical lattice for ^{87}Rb*	23
II.17	*Crossover from one to two dimensions of a trapped, spin polarized Fermi gas*	23
II.18	*Weakly linked binary mixtures of 87 Rb spinor BEC*	24
II.19	*Adiabatic Formation of Rydberg Crystals with Chirped Laser Pulses*	24
II.20	*Observation of spontaneous Bose-Einstein condensation and relaxation explosion of excitons at sub-Kelvin temperatures*	24
II.21	*Rydberg Interactions On An Atom Chip*	25
II.22	*Topological p_x+ip_y Superfluid Phase of Fermionic Polar Molecules*	25
II.23	*Strongly-interacting Fermi mixtures close to narrow resonances*	26
II.24	*Dynamic vortex unbinding following a quantum quench in bosonic mixtures*	26
II.25	*Superadiabaticity and the quantum speed limit in the dynamics of a two-level system*	26
II.26	*Ring trap for a rubidium BEC*	26
II.27	*An example of quantum anomaly in the physics of ultra-cold gases*	27
II.28	*Ultracold Bose gases in optical lattices: beyond the Bose-Hubbard model*	27
II.29	*Visibility of the Higgs mode in condensed matter and cold atoms systems*	27
II.30	*Atom Lasers in Optical Lattices: A New Generation of Coherent Matter Waves*	28
II.31	*Robustness of Topological Operations with Ultracold Atoms*	28

II.32	*Optical detection method for antiferromagnetic phase of fermionic atoms in an optical lattice*	28
II.33	*Designing atom and ion surface traps for quantum information processing*	29
II.34	*Quantum transitions for polar molecules*	29
II.35	*From Maxwell's Demon to Quantum Magnetism: Engineering and Probing Quantum Materials from the Ground Up*	29
II.36	*Limit of Spin Squeezing in Finite Temperature Bose-Einstein Condensates*	29
II.37	*Spectroscopy for cold atom gases in periodically phase-modulating optical lattices*	30
II.38	*Ultracold collisions in ring traps*	30
II.39	*Spontaneous persistent flow in a toroidal BEC after a rapid quench*	30
II.40	*Thermodynamics of a 2D Bose gas*	31
II.41	*Resonantly interacting Fermi-Fermi mixtures*	31
II.42	*Resonand Hawking Radiation in BECs*	31
II.43	*Spin-orbit coupled bosons superfluid*	31

Poster Session III: Thursday, September 15, 20:45-22:00

III.1	*Alain Aspect, TBA*	32
III.2	*Monte Carlo study of quantum phase diagram of Rydberg atoms with repulsive 1/r6 interaction*	32
III.3	*Supersolid Phases in Imbalanced Atomic Fermi Mixtures*	32
III.4	*Stability and many-body effects in dipolar mono- and bilayer fermionic systems*	33
III.5	*Universal Relations for Atoms with Large Scattering Length*	33
III.6	*Exploring the physics of disorder with a tunable Bose-Einstein condensate*	33
III.7	*Cavity-mediated long-range interactions in a dilute quantum gas*	33
III.8	*Remote Entanglement between a Single Atom and a Bose-Einstein Condensate*	34
III.9	*High sensitivity trapped Atom Interferometry with Bose Einstein Condensates*	34
III.10	*New results on Efimov physics and the creation of RbCs molecules*	34
III.11	*Solitons as the Early Stage of Quasicondensate Formation during Evaporative Cooling*	35
III.12	*Two-Photon-Spectroscopy of YbRb - Towards paramagnetic molecules*	35
III.13	*Atomic Einstein-Podolsky-Rosen entanglement detected by homodyning of matter wave fields*	35
III.14	*Phase-slips and the self-trapping regime of a bosonic Josephson junction*	35
III.15	*Hall conductivity of lattice bosons or "What is a hole condensate?"*	36
III.16	*Stability of spin-orbit coupled Fermi gases with population imbalance*	36
III.17	*Atom-atom interaction in line-centered optical lattices*	36
III.18	*Spin dynamics of a fragmented spinor BEC*	36
III.19	*Bose-Einstein condensate of Calcium-40*	37
III.20	*Optical Feshbach Resonances in BECs and Novel Quantum Degenerate Fermi Gases of Atomic Strontium*	37
III.21	*Guided atom laser interacting with complex potentials*	37
III.22	*Observation of a "blue" potassium MOT at 405nm*	38
III.23	*Characterisation of the multi-branch excitation spectrum of a strongly*	38

	correlated superfluid	
III.24	*Macroscopic superpositions by nonadiabatic stirring of a Tonks-Girardeau gas on a quasi-1D ring*	38
III.25	*Adiabaticity timescales in optical lattices*	39
III.26	*Disorder in spin-1 Bose Hubbard Model*	39
III.27	*An Atom-Chip Apparatus for Lightless Artificial Gauge Fields*	39
III.28	*Analytical approach to Bose-Einstein condensates on slightly biased double-well potentials*	40
III.29	*Many- body phases of dipolar gases*	40
III.30	*Self organization and sympathetic cooling of multispecies ensembles in a cavity*	40
III.31	*Correlated Rydberg ensembles in a dense atomic gas*	40
III.32	*Solitons in rapidly cooled 1D Bose gas*	41
III.33	*Anomalous diffusion of cold atoms in a 1D damped lattice*	41
III.34	*Tunneling Mechanisms in Strongly Correlated Bosonic Systems*	41
III.35	*Out-of-Equilibrium dynamics and transport in optical lattices*	42
III.36	*Tobias Tiecke, TBA*	42
III.37	*Controlling spin motion and interactions in a 1D Bose gas*	42
III.38	*Quantum Criticality from in-situ Density Imaging*	42
III.39	*Quantum simulation of frustrated magentism on a trinagluar optical lattice*	43
III.40	*Superfluidity and Anomalous Correlations in a Two-Dimensional Bose Gas*	43
III.41	*Memory of the initial conditions and dynamics of incomplete relaxation in a quantum cold-atomic system*	43
III.42	*Extraction of information from dynamics for strongly correlated systems/Disorder for spinor condensates in optical lattices*	44
III.43	*A trapped single ion inside a Bose-Einstein condesate*	44

I.1 BEC and guided atom optics in optical micro-potentials

G. Birkl et al.
TU Darmstadt

We present optimisation strategies for an all-optical BEC in a 1070 nm fiber-laser based dipole potential and our recent results on integrated atom-optics, based optical micro-potentials. These potentials can be created by various designs like cylindrical lens arrays or ring structures. A ring configuration, which offers a toroidal trapping potential, is currently investigated. We present first experiments with a Bose-Einstein condensate loaded to and accelerated in linear waveguides and the ring shaped dipole potential. With this setup we are able to perform interferometric experiments for characterisation of the coherence properties in a wave guide. We further show a possible scheme for an atom matter wave resonator with tunable mirror transmittance.

I.2 Bosonic and fermion mixtures of metastable neon and methods to control their collisions

G. Birkl et al.
TU Darmstadt

We investigate the collisional interactions of laser cooled, metastable neon (Ne*). The most remarkable feature of Ne* is its high internal energy. Since the internal energy exceeds half of the ionization energy it enables ionizing collisions, namely Penning ionization. Currently, we are investigating multi-isotope mixtures (including fermionic neon) and are exploring a method to manipulate the ionization cross-sections by preparing the atoms in superposition states of 3P2 Zeeman s...

I.3 Magnetic resonances in quantum degenerate helium

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At the LaserLaB of the Vrije Universiteit Amsterdam, we cool helium-4 as well as the fermionic isotope helium-3 to quantum degeneracy in a cloverleaf type magnetic trap. By overlapping a 1557-nm fiber laser with the evaporatively cooled cloud we transfer one of the isotopes, or a mixture of both, into an optical dipole trap to precisely measure the magnetic-dipole transition connecting the two metastable states and to investigate Feshbach resonances. The n=2 triplet S to n=2 singlet S transition has been measured in both isotopes to a relative precision of 8 parts per trillion providing a stringent test of two-electron QED theory and of nuclear few-body theory. Over the last months experiments have been performed to study two- and three-body losses in spin-polarized helium-4 (m=+1 and m=-1) as a function of magnetic field. Experiments are underway to observe a broad Feshbach resonance between helium-3 and helium-4 at approximately 1 kG that has recently been predicted using the Asymptotic Bound-state Model.

I.4 Density and spin fluctuations in trapped Fermi gases

J.-P. Brantut, J. Meineke, D. Stadler, T. Müller, S. Krinner and T. Esslinger
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We measure local density and spin fluctuations in a cold Fermi gas, using absoprtion imaging and shot-noise-limited interferometry.
Using the fluctuation-dissipation theorem, We relate the fluctuations of density to the compressibility of the cloud and demonstrate fluctuation-based, model independant thermometry. We also relate the spin fluctuations to the magnetic susceptibility of the cloud, and use it to infer entanglement. This constitutes a promising in-situ probe for correlated Fermi gases.

I.5 Crystalline phase for one-dimensional ultra-cold atomic bosons

H.P. Büchler
University of Stuttgart

We study cold atomic gases with a contact interaction and confined into one-dimension. Crossing the confinement induced resonance the correlation between the bosons increases, and introduces an effective range for the interaction potential. Using the mapping onto the sine-Gordon model and a Hubbard model in the strongly interacting regime allows us to derive the phase diagram in the presence of an optical lattice. We demonstrate the appearance of a phase transition from a Luttinger liquid with algebraic correlations into a crystalline phase with a particle on every second lattice site.

I.6 A quantum degenerate mixture of Rb and Cs

D.J.McCarron, H.W.Cho, D.L.Jenkin, M.P.Koppinger, K.L.Butler and S.L.Cornish
Durham University

We report a new method for the production of Bose-Einstein condensates of Cs and demonstrate the formation of a quantum degenerate mixture of Rb and Cs. The approach exploits efficient sympathetic cooling of Cs via Rb in a magnetic quadrupole trap prior to further evaporative cooling in a levitated optical trap. Sacrificing all the Rb during the cooling, we create single species Cs condensates of up to 6x10^4 atoms. Tailoring the evaporation to retain some Rb, we simultaneously create condensates of Rb and Cs in the same trapping potential, each containing up to 2x10^4 atoms. We observe a striking phase separation of the two species revealing the mixture to be immiscible due to strong repulsive interspecies interactions. We outline our plans for the production of ultracold heteronuclear molecules using this interesting system.

I.7 Non-equilibrium dissipative dynamics and heating of cold atoms in optical lattices

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A key challenge in current experiments with atoms in optical lattices is characterising and controlling heating processes, which can prevent the system from being cooled to sufficiently low temperatures to observe interesting quantum phases or dynamical properties. We study the dissipative many-body dynamics of cold atoms in optical lattices induced by heating processes including spontaneous emissions and noise on the lattice potential. The corresponding behaviour is intrinsically non-equilibrium, and a key aspect of the dynamics is the interplay between the form of the dissipation and the properties of the many-body state present in the system. We discuss how different heating mechanisms will differently affect the characteristic correlation functions of different many-body states, and also investigate to what extent states in different parameter regimes are able to thermalise in the presence of dissipation. We compute the dissipative dynamics based on quantum mechanical master equations and stochastic di...

I.8 Adiabatic quenches of quantum critical systems

Claudia De Grandi, Anatoli Polkovnikov
Boston University

We analyze the response of a quantum system when perturbed from its quantum critical point. In particular we consider the case of quenches with arbitrary power law dependence on time of the tuning parameter. Using adiabatic perturbation theory we find the scaling behaviour of several observables with the quench amplitude and the system size. We show that the universal scalings of those observables, as the excitation probability, the density of excited quasiparticles, the heat and the entropy, can be understood through the singularities at the critical point of some adiabatic susceptibilities, which are defined as a simple generalization of the fidelity susceptibility. We specify those results to the case of the sine-Gordon model, showing its connections to experimental realizations with cold atoms in one-dimension. In particular we discuss the relevance of these findings for the choice of the optimal protocol to load cold atoms in optical lattices.

I.9 Photoemission Spectroscopy in an Ultracold Fermi Gas: Investigating the Effects of Density Inhomogeneity

T. Drake, R. Paudel, J. Gaebler, D. S. Jin
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Ultracold atomic gases realize clean and controllable model systems for investigating many-body quantum physics. However, trapped gases are intrinsically spatially inhomogeneous in their density, and in many cases, one would like to compare measurements of these systems with theoretical understanding for a homogeneous gas. In particular, density inhomogeneity can complicate the interpretation of data taken in momentum space, as the original spatial information is lost during time of flight expansion. The effect of density inhomogeneity due to a harmonic trapping potential is studied in a degenerate gas of 40K atoms. Using a method to select only the atoms in the center of the trap, we study how trap averaging affects the results of time of flight experiments, including photoemission spectroscopy.

I.10 Exactly solvable models and ultracold Fermi gases

Angela Foerster*, Murray T. Batchelor, Xiwen Guan and Carlos C. N. Kuhn
* Instituto de Fisica da UFRGS

Exactly solvable models of ultracold Fermi gases are examined via their thermodynamic Bethe Ansatz solution.
Analytical and numerical results are obtained for the thermodynamics and ground state properties of two- and three-component one-dimensional attractive fermions with population imbalance.
For the three-component model, numerical solution of the dressed energy equations confirm that the analytical expressions for the critical fields and the resulting phase diagrams at zero temperature are highly accurate in the strong coupling regime. The results provide a precise

description of the quantum phases and universal
thermodynamics which are applicable to experiments with cold fermionic atoms confined to one-dimensional tubes.

Based on the work published in:
Journal of Statistical Mechanics, v. 12, p. P12014, 2010.
by M.T. Batchelor, A. Foerster, X.W. Guand and C. Kuhn

I.11 Strain and Dirac equations in optical lattices

J. J. Garcia-Ripoll, E. Alba, J. Mur-Petit, X. Fernandez, J. Pachos
CSIC, Univ. of Leeds

In this work we study how to simulate graphene-like lattices using optical potentials and the consequences of deforming the lattice structure and the lattice potential intensity locally. More precisely, we relate these perturbed lattices to the models of "strain" and "curvature" in graphene sheets and demonstrate that these deformations simulate a Dirac equation with Abelian and non-Abelian gauge potentials, as well as an effective spacetime metric.

I.12 Self-consistent number-conserving dynamics in a driven Bose-Einstein condensate

T. P. Billam and S. A. Gardiner
Durham University

We use the second-order, number-conserving formalism of Gardiner and Morgan [Phys. Rev. A 75, 043621 (2007)] to describe a Bose-Einstein condensate driven by periodic delta-kicks. In contrast to first-order descriptions, which predict rapid, unbounded growth of the noncondensate in resonant parameter regimes, the consistent treatment of condensate depletion in our fully-time-dependent, second-order description acts to damp this growth, leading to oscillations in the (non)condensate population and the coherence of the system.

I.13 BCS-BEC of ultracold fermions in the honeycomb lattice

Kean Loon LEE, Christian MINIATURA and Benoît GREMAUD
LKB-CNRS-CQT-NUS

The pairing properties (superfluidity...) of ultracold fermions, with an attractive interaction, loaded in an honeycomb (graphene-like) optical lattice are studied from a mean-field point of view. We emphasize the interplay due to the linear dispersion relation of the band structure around half-filling (i.e. the massless Dirac fermions) and the presence of an harmonic trap. In particular, the situation of an imbalance gas is discussed, emphasizing that, for large interaction, one observes a partial polarization in the center and a fully polarized one at the border of the trap. Then, the dynamical properties of the excitations are calculated within the Bogoliubov-De Gennes framework. Finally, we show how, going beyond the mean-field level, phase fluctuations can be taken into account,
allowing for a correct description of the BKT-like phase transition of the "condensation" of the preformed pairs.

I.14 How to BEC without Laser Cooling? - Loading a Conservative Trap from an Atomic Beam

Markus Falkenau, Valentin V. Volchkov, Jahn Rührig, Hannes Gorniaczyk, Tilman Pfau, Axel Griesmaier
5. Physikalisches Institut, Universität Stuttgart

We have realized a scheme for the fast accumulation and Bose-Einstein condensation of 52Cr atoms in a conservative potential loaded from a guided atomic beam [1]. Without laser cooling on a cycling transition, one dissipative step involving optical pumping allows us to load atoms at a rate of 2x10^7 atoms per second into the trap. The trapped cloud reaches a collisionally dense regime within less than 100 ms and we produce a Bose-Einstein condensate by subsequent evaporative cooling in less than 5 seconds. This constitutes a new approach to quantum degeneracy where Bose-Einstein condensation can in principle be reached without the need of a closed cycling transition. The much less restictive requirement of a transition suited for pumping between low- and high-field-seeking states should make this scheme applicable to a wider range of atomic - and possibly also molecular - species that are otherwise hard to cool.

[1] Falkenau et al. PRL 106, 163002 (2011)

I.15 An electron microscope for a gas of ultracold bosons

V. Guarrera, P. Wuertz, R. Labouvie, A. Vogler, G. Barontini, H. Ott
Technische Universität Kaiserslautern

The technique of scanning electron microscopy allows for the investigation of solid surfaces and structures with a spatial resolution of few nanometers. Extending the application of this tool to a cloud of ultracold atoms, we obtain a novel way to image and manipulate the gaseous target, characterized by high spatial resolution and by single atom sensitivity. A focussed electron beam is moved over the cloud and ionizes the atoms by electron impact ionization. The produced ions are subsequently extracted and detected. We successfully employed the technique for in situ observation of temporal correlations in a cold thermal cloud. The electron beam can also be used to locally introduce losses, thus paving the way to investigate dissipative processes in quantum gases and to generate topological defects.

I.16 A Magnetic Lattice for Ultracold Quantum Gases

S. Jose, L.Krzemien, S. Whitlock, P. Surendran, M. Singh, A. Sidorov, R. McLean and P. Hannaford
Swinburne University of Technology

Periodic magnetic lattices provide a promising alternative to optical lattices and have potential advantages of highly stable and reproducible potentials; of being able to tailor geometries of arbitrary shape; and of being ideally suited for mounting on an atom chip for practical devices. We report the trapping and cooling of Rb-87 F=1 , mF=-1 atoms in a 1D 10 micron-period permanent magnetic lattice on an atom chip. With controlled axial confinement we are able to load 3 x 10^5 atoms in about 100 lattice sites with a trap lifetime of about 12 s. RF spectroscopy indicates that an atom temperature of about 1-2 microkelvin which is close to the calculated BEC transition temperature. Using in situ absorption imaging we can spatially resolve the individual clouds in the 10 micron period magnetic lattice.

I.17 Spin-Asymmetric Josephson Effect, and Speed of Sound in the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) State

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We propose that with ultracold Fermi gases one can realize a spin-asymmetric Josephson effect in which the two spin components of a Cooper pair are driven asymmetrically — corresponding to driving a Josephson junction of two superconductors with different voltages for spin up and down electrons. We predict that the spin components oscillate at the same frequency but with different amplitudes. We explain this breakdown of the Cooper pair tunneling picture by describing the Josephson effect as interfering Rabi processes in which intermediate states with broken Cooper pairs account for the spin-asymmetry. [1]

We consider the density response of a spin-imbalanced Fermi gas in the FFLO state in an optical lattice. We calculate the collective mode spectrum of the gas in the generalized random phase approximation and show that the FFLO pairing leads to an anisotropic speed of sound. We also consider the damping of the collective modes. [2]

[1] PRL 105, 225301 (2010)
[2] arXiv:1103.0696v1; PRA (in press)

I.18 Sub-Poissonian fluctuations in a 1D Bose gas: from quantum quasi-condensate to the strongly interacting regime

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(2) Vienna Center for Quantum Science and Technology, Atominstitut, Austria
(3) School of Mathematics and Physics, The University of Queensland, Australia

We report on measurements of atom number fluctuations in small slices of a single 1D Bose gas on an atom-chip setup. By using current modulation techniques to prevent cloud fragmentation, we are able to probe the crossover from weak to strong interactions. In contrast to realizations of arrays of multiple 1D gases in 2D optical lattices, our experiments have allowed us to perform atom number fluctuation measurements in a single gas using in situ imaging. For weak interactions, we observe a continuous transition from super- to sub-Poissonian fluctuations as the density is increased, and we identify the relative importance of thermal and quantum fluctuation. At stronger interactions, the super-Poissonian region disappears, and the fluctuations go directly from Poissonian to sub-Poissonian, as expected for a fermionized gas. Our work opens up further opportunities in the study of 1D Bose gases, such as better understanding of the mechanisms of thermalization and the role of three-body correlations.

I.19 Proximity effects in ultracold bosons

Peter Krüger and Andrea Trombettoni
University of Nottingham and SISSA

We study the effects of spatially inhomogeneous interactions in ultracold bosonic gases. In such a scenario, proximity effects, as are well known for superconducting systems, can be investigated at superfluid to normal junctions. Here, the uniquely large degree of controllability of ultracold gases can be exploited, for example by tuning quantum depletion and/or introducing tunable (optical) lattice potentials.
We discuss possible experimental implementations based on microengineered environments near atom chips. Rather than the common use of locally controlled magnetic fields for external potential shaping, we now use this parameter for interaction strength adjustment near Feshbach resonances.

I.20 Probing Ultracold Atoms in Optical Lattices with Light Scattering

Hiro Miyake
MIT

A major thrust of the field of ultracold atoms in optical lattices has been to create novel phases of matter. Developing techniques to probe these systems is as important as the realization of such phases. We have applied the techniques of Bragg scattering and fluorescence imaging to study quantum degenerate bosonic rubidium-87 atoms from the superfluid phase to the Mott insulator phase in a 3D optical lattice. In particular, Bragg scattering can allow the direct detection of new phases such as antiferromagnetic ordering in 3D, both in the spin and occupation number sector.

I.21 Localization from quantum interference in one-dimensional disordered potentials

M. Moratti and M. Modugno
LENS - UPV/EHU - IKERBASQUE

We show that the tails of the asymptotic density distribution of a quantum wave packet that localizes in the the presence of random or quasiperiodic disorder can be described by the diagonal term of the projection over the eingenstates of the disordered potential. This is equivalent of assuming a phase randomization of the off-diagonal/interference terms. We demonstrate these results through numerical calculations of the dynamics of ultracold atoms in the one-dimensional speckle and quasiperiodic potentials used in the recent experiments that lead to the observation of Anderson localization for matter waves [Billy et al., Nature 453, 891 (2008); Roati et al., Nature 453, 895 (2008)]. For the quasiperiodic case, we also discuss the implications of using continuos or discrete models.

I.22 Probing the Equation of State of a Strongly Interacting Bose Gas

N. Navon, S. Piatecki, K. Günter, B. Rem, C. Nguyen, F. Chevy, W. Krauth, C. Salomon
Ecole Normale Supérieure

We measure the zero-temperature equation of state of a homogeneous Bose gas of ^{7}Li atoms by analyzing the in-situ density distributions of trapped samples. For increasing repulsive interactions our data shows a clear departure from mean-field theory and provides a quantitative test of the many-body corrections first predicted in 1957 by Lee, Huang and Yang. We further probe the dynamic response of the Bose gas to a varying interaction strength and compare it to simple theoretical models. We deduce a lower bound for the value of the universal constant $\xi>0.44(8)$ that would characterize the universal Bose gas at the unitary limit.

I.23 Quantum Atom Optics at work

T. Zibold, E. Nicklas, J. Tomkovic, H. Strobel, W. Müssel, I. Stroescu, C. Gross, M.K. Oberthaler

Kirchhoff Institut für Physik, Heidelberg University

This poster presentation gives an overview of the recent achievements in the Heidelberg group. In the context of quantum optics we will give details on the single photon beamsplitter experiment [1], the realization of a nonlinear interferometer surpassing the classical precision limit [2] and on recent results on EPR entanglement detected with atomic homodyning technique. We will also present how a classical bifurcation scenario [3] connecting the Rabi with the Josephson regime in a two mode problem. In this context also the demonstration of nonlinear dressed states for mixing/demixing control will be discussed. Finally the status of the experiment on generation of cat like states with bifurcation dynamics will be given.

[1] J. TomkoviÄ et al. Nature Physics (2011).
[2] C. Gross, et al. Nature 464, 1165 (2010).
[3] T. Zibold, et al. Phys. Rev. Lett. 105, 204101 (2010).

I.24 Microwave-Induced Feshbach Resonances

D. Papoular (1), G. Shlyapnikov (1), J. Dalibard (2)
(1) LPTMS, Universite Paris-Sud, France; (2) LKB, ENS, UPMC, France

The strength of the interactions in ultracold gases can be controlled using scattering resonances that occur in a low-energy collision between two atoms. These Fano-Feshbach resonances arise when the entrance collision channel is coupled to another channel that supports a weakly-bound molecular state. They are usually obtained using a static magnetic field. However, for some atoms, such as 23Na or 87Rb, all static-field resonances are narrow and occur for large magnetic fields, which severely limits their use in experiments. We propose an alternative to static-field FFRs where the coupling is achieved using a resonant microwave magnetic field. Our scheme is reminiscent of optical Feshbach resonances. It applies to any atomic species with a ground state that is split by hyperfine interaction. We discuss the case of the alkalis 7Li, 23Na, 41K, 87Rb, and 133Cs. In the case of 133Cs, the existence of a very weakly bound state yields a broad resonance, which we propose to observe with a Cesium fountain clock.

I.25 Multi-path Interferometer on Atom Chip

Jovana Petrovic, Ivan Herrera, Pietro Lombardi, Francesco Cataliotti
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Atom interferometers have been used in measurements of gravity, photon recoil and density correlations. Most of these measurements are based on 2-path setups. However, the precision of a M-path interferometer is predicted to surpass that of its 2-path analogue sqrt{M} times. So far, the multi-path interferometers have been experimentally demonstrated with optical fibres, optically pumped atom-beams and Bose-Einstein condensate (BEC) in optical lattice. Here we present a 5-path integrated atom interferometer with sensitivity close to theoretical predictions. It exploits Zeeman sublevels of the F=2 state of atoms in a BEC that are coupled by a single radio-frequency Rabi pulse, thereby eliminating the need for a tedious optical alignment. The interferometer is constructed by an addition of another, delayed, Rabi pulse and its output characteristics are controlled by changing the RF pulse. The inherent quasi-periodicity of M>3-level systems is analysed by a theory also applicable to a BEC in optical-lattice.

I.26 Correlated phases of bosons in tilted, frustrated lattices

Susanne Pielawa, Takuya Kitagawa, Erez Berg, Subir Sachdev
Harvard University

We study the `tilting' of Mott insulators of bosons into metastable states, which have rich possibilities for correlated phases with non-trivial entanglement of pseudospin degrees of freedom encoded in the boson density. We extend a previous study (Phys. Rev. B {\bf 66}, 075128 (2002)) of cubic lattices to a variety of lattices and tilt directions and in 2 dimensions: square, decorated square, triangular, and kagome. For certain configurations three-body interactions are necessary to ensure that the energy of the effective resonant subspace is bounded from below. We find quantum phases with Ising density wave order, with superfluidity transverse to the tilt direction, and a quantum liquid state with no broken symmetry. The existence of the quantum liquids state is shown by an exact solution for a particular correlated boson model. We also find cases for which the resonant subspace is described by effective quantum dimer models.

I.27 Interferometry with BEC in extended free fall

Ernst Maria Rasel

We present a status report about interferometry with extended wave packets at nk energy scales. Motivation is performing tests and measurements of gravity with quantum objects. The experiments reported here use a chip-based atom laser. Measuring the universality of propagation of matter waves touches the foundations of quantum mechanics and one of the pillars of general relativity: Einsteins Equivalence Principle.

I.28 Mass-imbalanced atomic mixtures in one-dimensional optical lattices

Tommaso Roscilde (1), Cristian Degli Esposti Boschi (2), Marcello Dalmonte (2)
(1) ENS de Lyon, (2) Università di Bologna

We present a comprehensive study of mass-imbalanced mixtures in one-dimensional optical lattices in the case of hardcore interactions between particles of the same species - describing spinful fermions, spinful hardcore bosons, or hardcore boson/fermion mixtures. Making use of quantum Monte Carlo and DMRG, we have explored the ground-state phase diagram of mixtures both at half filling and away from half filling, as well as in a parabolic trap. Our main results are the persistence of spin-charge separation and of an effective SU(2) symmetry even for strong mass imbalance in the repulsive case; the appearance of crystalline phases for strong mass imbalance both in the attractive and in the repulsive case for extreme mass imbalance; and the fundamental role played by both mass imbalance and a trapping potential in order to observe fully paired phases in attractive mixtures, even in presence of population imbalance.

I.29 Confinement-induced resonances revisited

S. Sala, P.-I. Schneider, A. Saenz
Humboldt University Berlin

About ten years ago confinement-induced resonances (CIR) were predicted to occur in (quasi) one-dimensional or two-dimensional systems. They are a rather universal phenomenon that is solely a consequence of the reduced dimensionality of the system. Last year, an experimental evidence for CIRs was found in ultracold atoms in optical lattices, but severe qualitative differences were observed with respect to theory. This raises the question, whether the original CIR theories are correct. In this work a new theoretical model based on the coupling of relative and center-of-mass motion is proposed that resolves all discrepancies and provides even astonishingly accurate quantitative agreement with the experimental results. The model is

furthermore successfully checked by a comparison with a full-dimensional ab initio calculation of two atoms in an anharmonic trap.

I.30 Spinor and polar lattice gases

Luis Santos
Leibniz University of Hannover

Spinor gases, formed by atoms with various available Zeeman substates, and polar gases, showing strong dipole-dipole interactions, provide a rich and interesting physics. We present some recent results concerning these systems in optical lattices. In a first part I will focus on lattice spinor gases, and more specifically on the possibility of different types of field-induced phase transitions in one-dimensional spin-3/2 fermions and spin-1 bosons, and on the use of the spin-degree of freedom in high-spin lattice fermions to cool pseudo-spin-1/2 fermions. In a second part we address some issues related with polar gases in deep optical lattices, including lattice-dependent condensate instability, soliton filamentation, entanglement spectrum of 1D polar gases, Haldane-insulator phases and interlayer BCS-BEC cross-over.

I.31 Quantum Dynamics and Thermalization

M. Gring, M. Kuhnert, T. Langen, T. Kitagawa, M. Schreitl, I. Mazets, D. A. Smith, E. Demler, and J. Schmiedmayer
Vienna Center for Quantum Science and Technology, Atominstitut, TU-Wien, Vienna, Austria; Harvard-MIT Center for Ultracold Atoms, Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Questions of relaxation processes in quantum many-body systems arise in many areas of physics ranging from cosmology to high-energy physics to condensed matter. We conducted an experimental study of equilibration dynamics of coherently split one-dimensional Bose gases through measurements of full distributions of matter-wave interference patterns on different length scales, which provides us with unprecedented information about the dynamical states of the system. Our analysis reveals the existence of two physically distinct regimes of relaxation, corresponding to phase diffusion and contrast decay. Following an initial rapid evolution, the distributions approach an apparent steady state characterized by an effective temperature eight times lower than the initial equilibrium temperature of the system. We associate this state with pre-thermalization.

I.32 Strontium quantum gases

Simon Stellmer, Mark Parigger, Rudi Grimm, and Florian Schreck
IQOQI, OEAW

Strontium is an alkaline-earth element. Its properties, as the existence of long-lived metastable states, narrow intercombination lines, and a ground state free of electronic magnetic moment, open exciting new possibilities for quantum simulation and computation. A necessary requirement for these applications is the availability of quantum degenerate gases. Here, we report on the achievement of quantum degeneracy in all four stable isotopes of strontium.

I.33 Beyond Mean-Field Effects on the Critical Temperature of a Trapped Bose Gas

Robert P Smith, Robert L D Campbell, Naaman Tammuz and Zoran Hadzibabic
University of Cambridge, UK

We perform high-precision measurements of the condensation temperature Tc of a 39K Bose gas with widely-tuneable interactions. For weak interactions we confirm mean-field predictions. However for sufficiently strong interactions we clearly observe, for the first time, an additional positive shift, characteristic of beyond-mean-field critical correlations. We also study non-equilibrium effects for both very weak and very strong interactions; in both regimes we observe evidence for super-heated condensates which survive above the equilibrium Tc.

http://arxiv.org/abs/1104.0890

I.34 Dynamics and decoherence of two cold bosons in a one-dimensional harmonic trap
T. Sowinski, M. Brewczyk, M. Gajda, K. Rzazewski
We study dynamics of two interacting ultracold Bose atoms in a harmonic oscillator potential in one spatial dimension. Making use of the exact solution of the eigenvalue problem of a particle in the δ-like potential, we study the time evolution of an initially separable state of two particles. The corresponding time-dependent single-particle density matrix is obtained and diagonalized, and single-particle orbitals are found. This allows us to study decoherence as well as creation of entanglement during the dynamics. The evolution of the orbital corresponding to the largest eigenvalue is then compared to the evolution according to the Gross-Pitaevskii equation. We show that if initially the center of mass and relative degrees of freedom are entangled, then the Gross-Pitaevskii equation fails to reproduce the exact dynamics and entanglement is produced dynamically. We stress that predictions of our study can be verified experimentally in an optical lattice in the low-tunneling limit.
PRA 82, 053631 (2010)

I.35 Collective oscillations in dipolar gases
Natalia Matveeva, Marta Abad, Alessio Recati and Sandro Stringari
Using sum rules and hydrodynamic theory we derive the collective frequencies for a quantum gas interacting with long range dipolar forces. Results are derived both in the superfluid and in the collisionless regime.

I.36 Quantum degenerate mixtures of alkali and alkaline-earth-like atoms
Yosuke Takasu, Hideaki Hara, Yoshifumi Yamaoka, Shuta Nakajima, Hideki Konishi, John Doyle, Yoshiro Takahashi
Kyoto University, JST-CREST, Harvard University

We realize simultaneous quantum degeneracy in mixtures consisting of the alkali and alkali-earthlike atoms Li and Yb. This is accomplished within an optical trap by sympathetic cooling of the fermionic isotope 6Li with evaporatively cooled bosonic 174Yb and, separately, fermionic 173Yb. We also measure the elastic s-wave scattering lengths of both Li-Yb combinations, and are consistent with mass-scaling analysis. The quantum degenerate mixtures of Li and Yb, as realized here, can be the basis for creation of ultracold molecules with electron spin degrees of freedom, studies of novel Efimov trimmers, and impurity probes of superfluid systems.
We also discuss our future plans to study strongly corelated system with our Yb-Li system.

I.37 The FFLO state and its expansion dynamics in lattices
D.-H. Kim, J. Kajala, F. Massel, J.J. Kinnunen, J.-P. Martikainen(*), and P. Törmä
Department of Applied Physics, Aalto University School of Science, Finland
(*) Nordita Stockholm, Sweden

We present real-space dynamical mean-field theory calculations for attractively interacting fermions in three-dimensional lattices with elongated traps. The critical polarization is found to be 0.8, regardless of the trap elongation. Below the critical polarization, we find unconventional superfluid structures where the polarized superfluid and Fulde-Ferrell-Larkin-Ovchinnikov-type states emerge across the entire core region. [1]
Expansion dynamics of interacting fermions in a lattice are simulated within the one-dimensional (1D) Hubbard model, using the essentially exact time-evolving block decimation (TEBD) method. We show that the Hubbard-dimer dynamics, combined with a two-fluid model for the paired and non-paired components of the gas, gives an efficient description of the full dynamics [2]. We consider an imbalanced gas, initially in presence of a confining trap potential. We investigate the dynamics of the initial state when the trap is switched off, showing how the expansion provides a signature of the FFLO state in a remarkably direct way. Namely, the unpaired particles expand with a velocity given by the FFLO wavevector q. [3]

[1] D.-H. Kim, J.J. Kinnunen, J.-P. Martikainen, and P. Törmä, Exotic superfluid states of lattice fermions in elongated traps, Phys. Rev. Lett. 106, 095301 (2011)
[2] J. Kajala, F. Massel, and P. Törmä, Expansion dynamics in the one-dimensional Fermi-Hubbard model, Phys. Rev. Lett. 106, 206401 (2011)
[3] J. Kajala, F. Massel, and P. Törmä, Expansion dynamics of the FFLO state, arXiv:1107.0282 (2011)

I.38 Quantum metrology with ultracold atoms on a chip

M. F. Riedel, P. Böhi, R. Schmied, C. Ockeloen, and P. Treutlein
University of Basel

We present our recent work on quantum metrology with ultracold atoms on an atom chip. In our experiment, we generate entanglement in a two-component Bose-Einstein condensate by tuning collisional interactions with a state-dependent microwave potential. We employ this technique to generate spin-squeezed states of the BEC that are a useful resource for quantum metrology with chip-based atomic clocks. The observed reduction in spin noise combined with the spin coherence implies multi-particle entanglement. To characterize the quantum state of the atoms, we have developed a new technique for quantum state tomography on the Bloch sphere and use it to reconstruct the Wigner function of the squeezed BEC. Moreover, we have used ultracold atoms for high-resolution imaging of microwave fields near on-chip waveguides. This novel technique is of interest for testing and optimizing integrated microwave circuits, which are at the heart of modern communication technology.

I.39 Density functional theory for ultracold atomic gases

P.N. Ma (1), S. Pilati (1), M. Troyer (1) and X. Dai (2)
(1) ETH Zurich and (2) IOP, Chinese Academy of Sciences

We will show how Kohn-Sham density-functional theory (DFT), which forms the basis of most electronic structure calculations in material science, can be applied to ultracold atomic gases in optical lattices. We present the derivation of an exchange correlation functional for atomic gases and show first applications within a local spin density approximation. In particular we will show that the local density approximation in DFT is much more accurate than what is commonly referred to as ``local density approximation'' in the atomic gases community. A first application that we will present is the phase diagram of a repulsively interacting Fermi gas in a shallow optical lattice, focusing on partially and fully polarized ferromagnetic phases and their competition with antiferromagnetism. As an outlook we will discuss how the development of DFT for ultracold atomic gases can form a strong link between materials science and atomic physics.

I.40 Shortcuts to adiabaticity for trapped ultracold gases

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We study, experimentally and theoretically, the controlled transfer of harmonically trapped ultracold gases between different quantum states. In particular we experimentally demonstrate a fast decompression and shift of a cold gas of non-interacting bosons as well as an interacting Bose-Einstein condensate as it would be obtained with an adiabatic process but only in a few dozens milliseconds. During the transfer the atomic sample goes through strongly out-of-equilibrium states while the external confinement is modified until the system reaches the desired stationary state. The scheme is theoretically based on the invariants of motion and scaling equations techniques and can be generalized to decompression trajectories including an arbitrary deformation of the trap.

I.41 Chiral superfluidity in higher bands of an optical lattice

Matthias Ölschläger, Thorge Kock, Georg Wirth, Andreas Hemmerich
Institut für Laserphysik, Universität Hamburg

Atoms trapped in optical lattices have been used successfully to study many-body phenomena. But the shape that bosonic ground-state wavefunctions can take is limited, compromising the usefulness of this approach. Such limitations, however, do not apply to excited states of bosons. The study of atomic superfluids realized in higher-energy bands, where orbital degrees of freedom are essential, can bring the world of optical lattices closer to relevant condensed matter systems. We discuss our observations of chiral superfluid order parameters in the P- and F-bands, which break the lattice symmetry and time-reversal symmetry.

I.42 Inter-band coupling induced novel condensates in a double-well lattice

Qi Zhou, J. V. Porto, S. Das Sarma
The Chinese University of Hong Kong,
Joint Quantum Institute at University of Maryland

We predict novel inter-band physics for bosons in a double-well lattice. An intrinsic coupling between the s and px band due to interaction gives rise to larger Mott regions on the phase diagram at even fillings than the ones at odd fillings. On the other hand, the ground state can form various types of condensates, including a mixture of single-particle condensates of both bands, a mixture of a single-particle condensate of one band and a pair-condensate of the other band, and a pair-condensate composed of one particle from one band and one hole from the other band. The predicted phenomena should be observable in current experiments on double-well optical lattices.

II.1 Disordered spin-1 Bose-Hubbard model

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(2) Dept. Física. Universitat Autònoma de Barcelona.
(3) Inst. Fizyki imienia Mariana Smoluchowskiego, Uniwersytet Jagielloaski.
(4) Mark Kac Complex Systems Research Center, Jagiellonian University

We study the zero temperature phase diagram of the spin-1 Bose Hubbard model in a two dimensional square lattice in the presence of disorder using a mean field Gutzwiller ansatz and a stochastic mean field approximation [M.Lacki et al. Phys. Rev. A 83, 013605 (2011)]. We focus here on the antiferromagnetic case. Disorder in the chemical potential can lead to the disappearance of Mott insulator lobes with an odd-integer filling factor and, for sufficiently strong spin coupling, to Bose glass of singlets between even-filling Mott insulator lobes. Disorder in the spinor coupling parameter results in the appearance of a Bose glass phase only between the n and the n+1 lobes for n odd. Disorder in the spinless interaction coupling inhibits Mott insulator regions for occupation larger than a critical value.

II.2 Long coherence time due to spin self-rephasing in an optical trap

J. Arlt, G. Kleine Büning, J. Will, W. Ertmer, E. Rasel, F. Ramirez-Martinez, F. Piechon, P. Rosenbusch, and C. Klempt
Department of Physics and Astronomy, Aarhus University
Institut für Quantenoptik, Leibniz Universität Hannover
LNE-SYRTE, Observatoire de Paris; Laboratoire de Physique des Solides, Univ. Paris-Sud

Optically trapped ensembles are of crucial importance for frequency measurements and quantum memories, but generally suffer from strong dephasing due to inhomogeneous density and light shifts. We demonstrate a drastic increase of the coherence time to 21 s on the magnetic field insensitive clock transition of 87Rb by applying a spin self-rephasing mechanism. This result confirms the general nature of the mechanism and its applicability in atomic clocks and quantum memories. An investigation of all relevant frequency shifts and noise contributions yields a stability of 2.4E-11 tau^(-1/2), where tau is the integration time in seconds. Based on a set of technical improvements, the presented frequency standard is predicted to rival the stability of microwave fountain clocks in a potentially much more compact setup.
http://arxiv.org/abs/1103.2283

II.3 Bose correlated states from gauge fields

B.Julia-Diaz, T.Grass,K.Günter,N.Barberan,M.Lewenstein,J.Dalibard
University of Barcelona

We present a new experimental route to build strongly correlated quantum states in systems of a few number (N $<$10) of ultracold atoms. The procedure involves the generation of a so-called artificial gauge field by considering two level atoms subjected to a suitable configuration of laser fields. By means of exact diagonalization techniques we show that for a large range of experimental parameters it is possible to attain strongly correlated quantum states, such as the Laughlin state. We discuss the properties of the ground state of the system in a broad range of experimental conditions outlining the best ones to observe a Laughlin type state. An analytical generalization of the Laughlin wave function is proposed which correctly describes the ground state of the system in the Laughlin-like domain.

II.4 Spin diffusion in Fermi gases

G. Bruun, C. J. Pethick and H. Fogedby

We examine spin diffusion in a two-component homogeneous Fermi gas in the normal phase. Using a variational approach, we show that the spin diffusion coefficient has a minimum for a temperature somewhat below the Fermi temperature with a value that approaches the quantum limit $\sim\hbar/m$ in the unitarity regime where m is the particle mass. The spin diffusion modes are then calculated in a trap with arbitrary geometry and the results are used to analyze recent experimental results.

II.5 Embedding a single quantum bit in an ultra-cold Fermi sea

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Single spin impurities embedded in Fermi gases or single atoms or ions combined with Bose-Einstein condensates are examples of a new class of quantum-hybrid systems. They offer the possibility for detailed investigations into the theory of quantum interactions and decoherence and the controlled simulation of different system-environment models synonymous with condensed matter physics and non-equilibrium statistical physics.
Here we consider a single quantum bit which is coupled to a low-dimensional, ultra-cold Fermi gas and show that any initial coherence in the qubit is quickly lost. We demonstrate that this is related to the presence of Anderson's orthogonality catastrophe, calculate the entropy of the system and the Loschmidt echo. The latter is closely related to the retarded Green's function, which allows us to calculate the spectral function of the gas. We show that its expected broadening in the orthogonality regime can be observed using Ramsey spectroscopy on the qubit.

II.6 The Hyperfine Molecular Hubbard Hamiltonian

Lincoln D. Carr and Michael L. Wall
Colorado School of Mines
An ultracold gas of heteronuclear dimer molecules with hyperfine structure loaded into a 1D optical lattice is investigated. The hyperfine molecular Hubbard Hamiltonian (HMHH) is derived from first principles. The large permanent electric dipole moment of these molecules gives rise to long-range dipole-dipole forces in a dc electric field and allows for transitions between rotational states in an ac microwave field. Additionally, a strong magnetic field can be used to control the hyperfine degrees of freedom independently of the rotational degrees of freedom. By tuning the angle between the dc electric and magnetic fields and the strength of the ac field, it is possible to control the number of internal states involved in the dynamics as well as the degree of correlation between the spatial and internal degrees of freedom. The HMHH’s unique features have direct experimental consequences such as quantum dephasing, tunable complexity, and the dependence of the phase diagram on the molecular state.

II.7 Dynamical instability of a spin spiral in an interacting Fermi gas as a probe of the Stoner transition

GJ Conduit & Ehud Altman
Weizmann Institute of Science

We propose an experiment to probe ferromagnetic phenomena in an ultracold Fermi gas, while alleviating the sensitivity to three-body loss and competing many-body instabilities. The system is initialized in a small pitch spin spiral, which becomes unstable in the presence of repulsive interactions. To linear order the exponentially growing collective modes exhibit critical slowing down close to the Stoner transition point. Also, to this order, the dynamics are identical on the paramagnetic and ferromagnetic sides of the transition. However, we show that scattering off the exponentially growing modes qualitatively alters the collective mode structure. The critical slowing down is eliminated and in its place a new unstable branch develops at large wave vectors. We demonstrate how the instabilities could be imaged which should allow experiments to detect the transition point and distinguish between the paramagnetic and ferromagnetic regimes.

II.8 Non-equilibrium flows and superfluid turbulence in dilute gas Bose-Einstein condensates

M. J. Davis, T. M. Wright, T. P. Simula, C. Feng, M. C. Garrett
University of Queensland and Monash University

Superfluids exhibit a number of intriguing properties, such as frictionless flow and quantised rotation in the form of vortices. Initially discovered in superfluid helium, both these phenomena have now been observed in dilute gas Bose-Einstein condensates. However, the isolation of ultra-cold gas systems from the environment combined with their inhomogeneous density profiles make the observation of other phenomena, such as the thermo-mechanical effect, more challenging in the lab.
The fundamental mechanism behind the superfluid thermo-mechanical effect is generating a sustained difference in the thermodynamic properties of the superfluid at spatially separated locations. This can be achieved in a single component dilute Bose gas by introducing a channel between two separated traps in which the initial state has different thermodynamic parameters. This will result in a non-equilibrium flow that can potentially achieve a steady state for sufficiently large reservoirs. Here we perform dynamical sim...

II.9 Probing magnetic order in ultracold lattice gases

G. De Chiara, O. Romero-Isart, A. Sanpera

A forthcoming challenge in ultracold lattice gases is the simulation of quantum magnetism. That involves both the preparation of the lattice atomic gas in the desired spin state and the probing of the state. Here we demonstrate how a probing scheme based on atom-light interfaces gives access to the order parameters of nontrivial quantum magnetic phases, allowing us to characterize univocally strongly correlated magnetic systems produced in ultracold gases. This method, which is also nondemolishing, yields spatially resolved spin correlations and can be applied to bosons or fermions. As a proof of principle, we apply this method to detect the complete phase diagram displayed by a chain of (rotationally invariant) spin-1 bosons.

II.10 s-Wave Interaction in a Two-Species Fermi-Fermi Mixture at a Narrow Feshbach Resonance

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(1) Ludwig-Maximilians-University of Munich, (2) Centre for Quantum Technologies and National University of Singapore

We investigate s-wave interactions in a two-species Fermi-Fermi mixture of 6-Li and 40-K. We develop for this case the method of cross-dimensional relaxation and find from a kinetic model, Monte Carlo simulations, and measurements that the individual relaxation rates differ due to the mass difference. The method is applied to measure the elastic cross section at the Feshbach resonance that we previously used for the production of heteronuclear molecules. Location (B0=154.71(5) G) and width are determined for this resonance. This reveals that molecules are being produced on the atomic side of the resonance within a range related to the Fermi energies, therefore establishing the first observation of a many body effect in the crossover regime of a narrow Feshbach resonance.

II.11 Topologically protected Majorana Edge States from Dissipation

S. Diehl, E. Rico, M. Baranov, P. Zoller
Institute for Quantum Optics and Quantum Information

We show the emergence of topological features in dissipative systems of cold atomic fermions. In particular, we study the case of a one-dimensional driven dissipative Kitaev wire. The key feature is the existence of an invariant subspace hosting Majorana edge modes, and the dissipative dynamics acts to sharply isolate this subspace from the bulk via the Quantum Zeno effect. We demonstrate robustness against static disorder as well as nonabelian braiding statistics, obtained from adiabatic parameter changes in the Liouville operator generating dissipative dynamics. We identify the proper topological invariant in terms of the density matrix, underpinning that topological features are intrinsically related to the statistical, or occupation number, properties, while the physical protection is tied to spectral properties.

II.12 Frustrated quantum antiferromagnetism with spinless bosons

Andre Eckardt
ICFO (Barcelona)

Considering cold atoms in an optical lattice, we show that off-resonant lattice shaking can be used to invert the tunneling matrix elements from standard negative to positive values [Eckardt et al., EPL 89, 10010 (2010)]. For non-bipartite lattices this has dramatic consequences. The ground-state of a Bose condensate in a triangular lattice becomes two-fold degenerate and breaks time-reversal symmetry by featuring currents around the plaquettes. In a collaboration with the Sengstock group, this effect has been observed experimentally [Struck et al., arXiv:1103.5944]. For increasing interaction and anisotropic tunneling, quantum fluctuations can eventually destroy the symmetry breaking in favor of a unique superfluid state. In the hard-core boson limit, the system is described by the quantum XY model (with large spin coupling of the order of boson hopping) for which exotic spin-liquid states are expected. This opens a novel route towards the quantum simulation of frustrated magnetism.

II.13 Probing an ultracold atomic crystal with matter waves

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We experimentally study the scattering of matter waves from ultracold atoms held in an optical lattice. Using a one-dimensional Bose gas as a source of matter waves incident on an atomic Mott insulator, we are able to infer the atoms' spatial ordering and on-site localization. In tuning the depth of the optical lattice localizing the atoms, we furthermore observe a suppression of elastic two-body collisions in the band structure. The scattering of neutral atoms should find utility as a versatile probe of atomic many-body systems.

II.14 BCS-BEC crossover in a 2D Fermi gas

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We investigate the crossover from Bardeen-Cooper-Schrieffer (BCS) superfluidity to Bose-Einstein condensation (BEC) in a two-dimensional Fermi gas at T=0 using the fixed-node diffusion Monte Carlo method. We calculate the equation of state and the gap parameter as a function of the interaction strength, observing large deviations compared to mean-field predictions. In the BEC regime our results show the important role of dimer-dimer and atom-dimer interaction effects that are completely neglected in the mean-field picture. Results on Tan's contact parameter associated with short-range physics are also reported along the BCS-BEC crossover.

II.15 Ultracold fermions in a tunable honeycomb optical lattice

Daniel Greif, Thomas Uehlinger, Gregor Jotzu, Leticia Tarruell, and Tilman Esslinger
Institute for Quantum Electronics, ETH Zurich

The properties of solid-state materials are crucially influenced by the topological properties of their band structure. A prime example is the honeycomb lattice, where the presence of topological defects in the Brillouin zone - the Dirac points - leads to novel physical phenomena like those observed in graphene. Ultracold fermions in optical lattices provide an ideal system to simulate the properties of materials, as its parameters can be controlled in a wide range. Here we realize a lattice potential with a tunable structure, including the honeycomb geometry, using a two-dimensional optical superlattice for ^{40}K atoms. We observe the emergence of topological defects in the bands by means of transport measurements. Both the appearance of the Dirac points and their position inside the Brillouin zone are in excellent agreement with ab initio calculations. Our results pave the way towards the realization of topological phases in optical lattices or, in the presence of interactions, the observation of quantum spin liquids.

II.16 Two dimensional bi-chromatic optical lattice for ^{87}Rb

Jennie Guzman, Gyu-Boong Jo, Claire Thomas, Dan Stamper-Kurn
University of California Berkeley

We report on the recent development of a two-dimensional bi-chromatic optical lattice using ultracold {87}^Rb atoms. The bi-chromatic lattice consists of overlaying two commensurate wavelength triangular lattices. Adjusting the relative position of these two lattices, we are able to explore different lattice geometries, including a kagome lattice. We demonstrate the different lattice geometries using two techniques: Kapitza-Dirac diffraction and Bose-Einstein condensate interference out of the lattice.

II.17 Crossover from one to two dimensions of a trapped, spin polarized Fermi gas

F. Heidrich-Meisner, A. Feiguin, D. Huse
LMU Munich, U Wyoming, Princeton University

The physics of spin-imbalanced Fermi gases is a topic of great timely interest because of the possibility of observing the one-dimensional (1D) version of an Fulde-Ferrell-Larkin-Ovchinnikov

(FFLO) state in experiments [1]. While theoretically, in a truly one-dimensional system, there are always FFLO correlations, the question arises how this state
evolves upon coupling chains to a 2D or 3D ensemble. We address this point
by considering the ladder geometry, which captures some essential features of a 2D system and allows for a numerically exact solution.
In this work, we focus on the changes in the density profiles of a
trapped system, both for the case of an adiabatic increase of the
transverse coupling and for a fast switching of this coupling.
To address the latter point, we utilize time-dependent DMRG simulations.

[1] Y. Liao et al, Nature 467, 567 (2010)
[2] A. Feiguin and F. Heidrich-Meisner,
Phys. Rev. Lett. 102, 076403 (2009)

II.18 Weakly linked binary mixtures of 87 Rb spinor BEC

M. Mele-Messeguer, B. Julia-Diaz, M. Guilleumas, A. Polls, A. Sanpera
UB, UAB

We present a study of binary mixtures of Bose–Einstein condensates confined in a double-well potential within the framework of the mean field Gross–Pitaevskii (GP) equation. We re-examine both the single component and the binary mixture cases for such a potential, and we investigate what are the situations in which a simpler two-mode approach leads to an accurate description of their dynamics. We also estimate the validity of the most usual dimensionality reductions used to solve the GP equations. To this end, we compare both the semi-analytical two-mode approaches and the numerical simulations of the one-dimensional (1D) reductions with the full 3D numerical solutions of the GP equation. Our analysis provides a guide to clarify the validity of several simplified models that describe mean-field nonlinear dynamics, using an experimentally feasible binary mixture of an F = 1 spinor condensate with two of its Zeeman manifolds populated, m = ±1.

New J. Phys. 13 033012 (2011)

II.19 Adiabatic Formation of Rydberg Crystals with Chirped Laser Pulses

R. M. W. van Bijnen, S. Smit, K. A. H. van Leeuwen, E. J. D. Vredenbregt, and S. J. J. M. F. Kokkelmans
Department of Physics, Eindhoven University of Technology, Eindhoven, The Netherlands

Ultracold atomic gases have been used extensively in recent years to realize textbook examples of condensed matter phenomena. Recently, phase transitions to ordered structures have been predicted for gases of highly excited, "frozen" Rydberg atoms. Such Rydberg crystals are a model for dilute metallic solids with tunable lattice parameters, and provide access to a wide variety of fundamental phenomena. We investigate theoretically how such structures can be created in four distinct cold atomic systems, by using tailored laser-excitation in the presence of strong Rydberg-Rydberg interactions. We study in detail the experimental requirements and limitations for these systems, and characterize the basic properties of small crystalline Rydberg structures in one, two and three dimensions [1].

[1] R. M. W. van Bijnen, S. Smit, K. A. H. van Leeuwen, E. J. D. Vredenbregt, and S. J. J. M. F. Kokkelmans, arXiv:1103.2096

II.20 Observation of spontaneous Bose-Einstein condensation and relaxation explosion of excitons at sub-Kelvin temperatures

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While cold atoms provide a new arena for BEC, it has still been a non-trivial quest whether nature chooses a form of exciton BEC, since electrons and holes are complex quantum systems with strong Coulomb correlations. Paraexcitons of Cu2O have been studied for decades because their decoupling from the radiation field makes them possible to form a coherent matter-like wave in an equilibrium condition, in contrast to cavity-polaritons. However, our recent measurements revealed that an enhanced inelastic collision prevents the BEC at liquid helium-4 temperature where the effective lifetime is too short at the critical density. We cooled excitons to sub-Kelvin in a trap and crossed the phase boundary for BEC at a much lower critical density. We successfully reached the point and found that BEC manifests itself as the relaxation explosion as has been discussed in atomic hydrogen. This observation shows that dilute excitons are purely bosonic and undergo the quantum phase transition in this inelastic environment.

II.21 Rydberg Interactions On An Atom Chip

V. Leung, A. Tauschinsky, H.B. van Linden van den Heuvell, and R.J.C. Spreeuw
U of Amsterdam

We report on our progress towards quantum information science using two-dimensional lattices of mesoscopic ensembles on a magnetic-film atom chip. We have demonstrated that a few hundred microtraps of 10 - 100 ^{87}Rb atoms can be individually resolved, optically addressed, and spatially manipulated as a shift register [1]. We are currently investigating the use of the dipole blockade mechanism to realize switchable, Rydberg mediated interactions in a lattice on the 5μm length scale.
In addition we have used the spectroscopy of electromagnetically induced transparent (EIT) transitions to characterize the level shifts and broadenings of the Rydberg states near the surface [2]. Our studies open the way to studies of dipolar physics, collective excitations, quantum metrology, and quantum information processing involving interacting Rydberg excited atoms on atom chips.

[1] S. Whitlock, et al., New J. Phys. 11, 023021 (2009)
[2] A. Tauschinsky, et al., Phys. Rev. A 81, 063411 (2010)

II.22 Topological p_x+ip_y Superfluid Phase of Fermionic Polar Molecules

J. Levinsen 1,2, N. R. Cooper 1,2, G. V. Shlyapnikov 2,3,4
1 University of Cambridge, 2 Universite Paris Sud XI, 3 Van der Waals-Zeeman Institute Amsterdam, 4 KITP Santa Barbara

We discuss the topological px+ipy phase in a 2D gas of fermionic polar molecules dressed by a circularly polarized microwave field. This phase emerges since the molecules may interact via a potential that has an attractive dipole-dipole r^{-3} tail, providing p-wave superfluid pairing at fairly high temperatures. We calculate the amplitude of elastic p-wave scattering taking into account both anomalous scattering due to the tail and the short-range contribution. The amplitude is then used for the analytical and numerical solution of the gap equation. The critical temperature can be varied within a few orders of magnitude by modifying the short-range part of the potential. The decay of the system via relaxation of molecules to states with lower energies is

slow due to the necessity of a large momentum transfer. The lifetime of the system can be of the order of seconds at 2D densities~10^9 cm^-2. This leads to T_c of up to a few tens of nK making it realistic to obtain the topololigical px+ipy superfluid phase.

II.23 Strongly-interacting Fermi mixtures close to narrow resonances

Pietro Massignan
ICFO

We investigate here the properties of a population-imbalanced heteronuclear Fermi-Fermi mixture in the vicinity of a narrow Feshbach resonance. We calculate the relevant quasi-particle properties (energy, effective mass, residue, and lifetimes) of the attractive and repulsive polaronic branches, and of the shallow molecule, and predict the associated rf-spectra. Finally, we show how the use of light impurities is helpful towards the experimental realization of itinerant ferromagnetism.

II.24 Dynamic vortex unbinding following a quantum quench in bosonic mixtures

Ludwig Mathey (1), Kenneth Guenter (2), Jean Dalibard (2), Anatoli Polkovnikov (3), Charles Clark (4)
Center for Optical Quantum Technologies (1), Laboratoire Kastler Brossel, ENS (2), Boston University (3), Joint Quantum Institute (4)

We study the many-body dynamics of a mixture of two hyperfine states of bosonic atoms in 2D, following a pi/2-pulse. Using both a numerical implementation of the Truncated Wigner approximation and an analytical approach, we find that a dynamic phase transition can be triggered, in which the system relaxes from a superfluid to a disordered state via vortex unbinding. This process can be dynamically suppressed, which creates a long-lived metastable supercritical state. We discuss the realization and detection of these effects.

II.25 Superadiabaticity and the quantum speed limit in the dynamics of a two-level system

O. Morsch, E. Arimondo, M. Bason, D. Ciampini, R. Fazio, V. Giovannetti, N. Malossi, R. Mannella, M. Viteau
INO-CNR and Dipartimento di Fisica, Pisa; NEST, Scuola Normale Superiore and Istituto di Nanoscienze-CNR, Pisa, Italy

The Landau-Zener model for the dynamics of a system of two coupled quantum states exhibiting a level crossing is a paradigm of quantum physics. Here we investigate different protocols using non-linear sweeps of the control parameter in the Landau-Zener model in order to either maximize the probability of remaining in the adiabatic ground state, or to minimize the sweep duration. The latter protocol realizes the quantum speed limit for the evolution of a quantum system. If the coupling strength is also allowed to vary in time, it becomes possible to construct sweeps that make the evolution superadiabatic, in which case the system remains perfectly in the adiabatic ground state at all times, even for finite sweep durations. We show how such superadiabatic evolutions can be demonstrated using BECs in accelerated optical lattices. We also show that superadiabatic sweeps are extremely robust to a variation of the sweep duration and coupling strength, which should make them interesting for practical applications.

II.26 Ring trap for a rubidium BEC

R. Dubessy, K. Merloti, T. Liennard, L. Longchambon, P.-E. Pottie, A. Perrin, V. Lorent and H. Perrin

Laboratoire de physique des lasers, CNRS and Université Paris 13

A new experimental setup for the production of Bose-Einstein condensates (BEC) in annular traps has been developed. The aim of the experiment is to study the superfluid properties of degenerate gases. 87Rb atoms are cooled to degeneracy in a quadrupolar trap plugged by a blue detuned laser. The dynamics of the evaporation is dominated by the linear trap down to 100 µK where the plug beam starts to play a role. At this point, the quadrupolar field is reduced to increase the weight of the plug beam and further reduce Majorana losses and subsequent heating. The repulsive barrier of height 150 µK provided by the laser is then high enough to suppress Majorana spin flips. The atomic cloud splits into two, the trap presenting two minima spaced by about 100 µm on each side of the plug beam. The population in the two wells can be controlled by adjusting the position of the laser. BEC with 2.10^5 atoms are produced in one of the wells in about 20 s. Once condensed, the atoms will be transferred in the ring trap.

II.27 An Example of Quantum Anomaly in the Physics of Ultra-Cold Gases
Maxim Olshanii[1,2], Hélène Perrin[2], and Vincent Lorent[2]
[1]Department of Physics, University of Massachusetts Boston, Boston Massachusetts 02125, USA
[2]Laboratoire de physique des lasers, Institut Galilée, Université Paris 13 and CNRS, 99 avenue J.-B. Clément, F-93430 Villetaneuse, France

We propose an experimental scheme for observation of a quantum anomaly— quantum-mechanical symmetry breaking — in a two-dimensional harmonically trapped Bose gas. The anomaly manifests itself in a shift of the monopole excitation frequency away from the value dictated by the Pitaevskii-Rosch dynamical symmetry. While the corresponding classical Gross-Pitaevskii equation and the derived from it hydrodynamic equations do exhibit this symmetry, it is violated under quantization. The resulting frequency shift is of the order of 1% of the carrier, well in reach for modern experimental techniques. We propose using the dipole oscillations as a frequency gauge.

II.28 Ultracold Bose gases in optical lattices: beyond the Bose-Hubbard model
S. Pilati, M. Troyer
Theoretische Physik, ETH Zurich

Due to their accessibility and the possibility to tune the most relevant physical parameters, ultracold gases in optical lattices represent the ideal toolbox to explore the intriguing properties of strongly correlated many-body systems.
So far, most theoretical and experimental studies of these systems have addressed the regime of weak interatomic interactions and large optical lattice intensities, where the system is fairly-well described by the single-band Hubbard model. In this work, we employ a novel continuous-space quantum Monte Carlo method which allows to simulate bosonic systems at arbitrary optical lattice intensity and interaction strength. We determine the critical parameters for the superfluid-to-insulator transition addressing also the regime of large s-wave scattering length and weak laser intensities, thus expanding the phase diagram to a regime that cannot be investigated using a single band model.
We discuss how this technique could be extended to fermionic systems.

II.29 Visibility of the Higgs mode in condensed matter and cold atoms systems
D. Podolsky
Technion

The Higgs mode is a ubiquitous collective excitation in condensed matter systems with broken continuous symmetry. It is expected to appear in superfluids near the Mott transition, polar condensates, antiferromagnets, superconductors, and charge density waves.
Detection of the amplitude mode is a valuable test of the underlying field theory, and its mass gap is a measure of proximity to a quantum critical point. However, since the amplitude mode can decay into low energy Goldstone modes, its experimental visibility has been questioned. Here I show that the visibility depends on the symmetry of the measured susceptibility. In particular, scalar (rotationally invariant) measurements allow for the observation of a sharp amplitude peak throughout the ordered phase. I propose experimental setups to measure the amplitude peak in various physical systems.

II.30 Atom Lasers in Optical Lattices: A New Generation of Coherent Matter Waves

I. Hen and M. Rigol
Georgetown University

The invention of the first optical lasers more than half a century ago marked the beginning of our ultimate control over light. More recently, with the realization of Bose-Einstein condensation, we are entering an era in which a similar degree of control over matter waves is being achieved. Much effort has been devoted in converting Bose-Einstein condensates into freely propagating coherent matter waves - the so called atom lasers, which are expected to become constituents in future devices. Here, we address the possibility of gaining unique control over coherent matter waves by enhancing interactions utilizing optical lattices. We show that the free expansion of strongly interacting bosons in an optical lattice, starting from a Mott insulator, leads to Bose-Einstein condensation at nonzero momenta. Those momenta can be fully controlled by tuning the lattice parameters. The correlated matter waves created this way open the door to a new generation of atom lasers.

II.31 Robustness of Topological Operations with Ultracold Atoms

L. Mazza*, H.H. Tu*, M.D. Lukin#, J.I. Cirac*, M. Rizzi*
*Max Planck Quantenoptik - Garching // # Harvard University - Cambridge (MA)

Since the discovery of quantum Hall effect, topological fluids, i.e. gapped states with conducting edges labelled by a topological invariant, have influenced the research of diverse communities. Among their exotic properties, quasiparticles obeying unconventional statistics, called anyons, are surely one of the most seducing. Their braiding, i.e. controlled exchange of positions, has been proposed as a possible implementation for quantum computation.
The exquisite control reached in ultracold atomic setups might indeed provide a solution for the long-standing quest towards a manipulable toolbox for anyons.
Here we propose a setup based on fermionic atoms and molecules where not only a p+ip model is realized but also anyons can be created and manipulated at will. Indeed gap-protected anyons are trapped inside vortices created by mobile external lasers.
In order to investigate the effective robustness of such a device for practical purposes, we study braiding fidelity in presence of various noise sources.

II.32 Optical detection method for antiferromagnetic phase of fermionic atoms in an optical lattice

F. Cordobes-Aquilar, A. F. Ho, J. Ruostekoski
University of Southampton and Royal Holloway University of London

We analyze the optical response of an interacting two-species fermionic atomic gas in a 2D optical lattice and show how the diffraction peaks and the fluctuations of the scattered light provide information about antiferromagnetic correlations and temperature of the atoms.

II.33 Designing atom and ion surface traps for quantum information processing
Roman Schmied (1), Janus Wesenberg (2), Dietrich Leibfried (3)
(1) University of Basel, Switzerland; (2) National University of Singapore; (3) NIST Boulder, USA

Progress in the bottom-up construction of interacting quantum systems (e.g. quantum simulators of lattice spin models) depends crucially on the fabrication of microstructured arrays of traps. Within such microtraps, the carriers of quantum information (whether single atoms, ions, BECs, or a mixture of these) can be controlled individually and with excellent flexibility; the interactions between microtraps can be taylored to any desired geometry. We present optimizing methods for designing complicated trap geometries, and review recent experimental progress in their fabrication: microtrap lattices for ultracold atoms being fabricated at the University of Amsterdam, and few-ion cluster traps in a collaboration with Sandia/Boulder/Freiburg. We propose a quantum simulator for the hexagonal Kitaev model, to be implemented with an array of microtrapped ions on an optimized surface-electrode chip. This quantum simulator promises an experimental foray into the simulation of topological phases with trapped ions.

II.34 Quantum transitions for polar molecules
Georgy Shlyapnikov
LPTMS, Univ. Paris Sud, Bat.100, 91405 Orsay, France

I will discuss quantum phase transitions that are supposed to emerge in bilayer systems of fermionic polar molecules. Of particular interest will be the transition from a p-wave interlayer superfluid to the (s-wave) Bose-Einstein condensation of interlayer dimers.

II.35 From Maxwell's Demon to Quantum Magnetism: Engineering and Probing Quantum Materials from the Ground Up
J. Simon, W. Bakr, R. Ma, M. Eric Tai, P. Preiss, M. Greiner
Harvard University

Cold atoms in optical lattices provide a unique opportunity to engineer exotic quantum materials from fundamental building blocks. We describe recent successes in constructing, manipulating and imaging such materials using our high resolution quantum gas microscope. We present the first optical lattice realization of a quantum magnet, observing in situ the quantum phase transition between a paramagnet and an antiferromagnet. We also introduce a novel orbital excitation blockade mechanism that we employ to create a Maxwell demon for in-lattice cooling and entropy removal, and to image many-body states. This growing toolbox has bright prospects from studies of spin liquids and topological physics to quantum information processing and beyond.

II.36 Limit of Spin Squeezing in Finite Temperature Bose-Einstein Condensates
A. Sinatra, E. Witkowska (*), J.-C. Dornstetter, Yun Li, Y. Castin
Laboratoire Kastler Brossel Ecole Normale Superieure, UPMC and CNRS, (*) Instiute of Physics Polish Academy of Sciences

We show that, at finite temperature, the maximum spin squeezing achievable using interactions in Bose-Einstein condensates has a finite limit when the atom number $N\to \infty$ at fixed density and interaction strength. We calculate the limit of the squeezing parameter for a spatially homogeneous system and show that it is bounded from above by the initial non-condensed fraction.
arXiv:1104.1871

II.37 Spectroscopy for cold atom gases in periodically phase-modulating optical lattices
Akiyuki Tokuno and Thierry Giamarchi
DPMC-MaNEP, University of Geneva

Cold atoms in optical lattices are vigorously studied as a new platform providing strongly correlated quantum states. However, in addition to realizing such systems, the ability to probe them is important.
We propose a novel spectroscopy in cold atom experiments by using periodic phase-modulation of optical lattice potentials. Corresponding to the statistics of atoms, we formulate the different observables in the linear response theory: The energy absorption rate for bosonic atom gases, and the doublon production rate for fermionic atom gases. Interestingly they are given by the imaginary part of the retarded current correlation function well-known as a quantity corresponding to an optical conductivity.
Furthermore, as an example, we discuss the current-current correlation functions of Mott insulating states in one, two and three dimensional Bose systems, and also compare our spectroscopy with another known spectroscopy by amplitude-modulation of an optical lattice.

II.38 Ultracold collisions in ring traps
Manuel Valiente, Klaus Molmer
LTC and Department of Physics & Astronomy, Aarhus University

Low-energy collisions of ultracold bosonic atoms in ring-shaped traps are considered. First, the problem is studied with a shallow, attractive ring potential via a full 3D calculation, and an approximate symmetry for odd or even winding numbers is found, which profoundly affects the collisional properties. We then use a more idealized model on a discrete lattice to describe how confinement-induced resonances are modified by the ring geometry, and show how ring (or other arbitrary) traps supporting a continuum of states with or without resonances -- which have been discarded in previous studies -- can be addressed.

II.39 Spontaneous persistent flow in a toroidal BEC after a rapid quench
K. C. Wright, R. B. Blakestad, A. Ramanathan, W. D. Phillips, G. K. Campbell
Joint Quantum Institute, NIST Gaithersburg

We have observed spontaneous formation of persistent currents in a toroidal BEC after evaporation into the condensed state. In the Kibble-Zurek (KZ) description of symmetry-breaking phase transitions, fluctuations in the order paprameter may be "frozen out" as the system is quenched through the critical regime, resulting in topological defects whose density scales with the quench rate. In a ring geometry (the configuration originally proposed by Zurek), this translates into a finite probability for a non-zero phase winding around the ring after the quench, i.e. quantized circulation. In our system, these circulating states are robust and extremely long-lived, enabling accurate counting of defects at long times, well after other excitations have settled. We report our observations of spontaneous circulation for a range of experimental conditions, and compare these observations with KZ predictions.

II.40 Thermodynamics of a 2D Bose gas

Tarik YEFSAH, Rémi DESBUQUOIS, Kenneth J. GUENTER, Lauriane CHOMAZ, Jean DALIBARD
ENS Paris - Jean Dalibard Group

In this poster I will present our recent experimental work on the thermodynamics of a quasi-2D Bose gas. An intriguing feature of this system is that interactions do not introduce any length scale and are described by a dimensionless parameter. As a consequence the equation of state of the homogeneous system is scale invariant, which we prove by performing measurements on several samples prepared at various temperatures and chemical potentials.

Another interesting aspect of the 2D Bose gas is its pre-superfluid phase. This phase, which is referred to as a "quasi-condensate", is characterized by a strong reduction of density fluctuations. I will present experimental measurements of the interaction energy in our trapped 2D Bose gases, which evidence the emergence of this rigid phase.
Finally, I will report on direct observation of vortices in superfluid samples, which constitute the key ingredient of the microscopic theory for this superfluid transition.

II.41 Resonantly interacting Fermi-Fermi mixtures

M. Zaccanti, C. Kohstall, A. Trenkwalder, M. Jag, F. Schreck, R. Grimm
IQOQI & University of Innsbruck

In the last few years, mixtures of two ultracold fermionic species with tunable interactions have become experimentally available. We recently demonstrated the possibility of realizing a strongly interacting Fermi-Fermi mixture of 6Li-40K at a heteronuclear Feshbach resonance [Trenkwalder et al., Phys. Rev. Lett. 106, 115304 (2011)], paving the way to investigation of many- body phenomena in such a system. Here, I will discuss the most recent activities of our group, with special focus on radio-frequency spectroscopy on the Li-K mixture.

II.42 Resonand Hawking Radiation in BECs

Ivar Zapata, Mathias Albert, Renaud Parentani, Fernando Sols

We study double-barrier interfaces separating regions of subsonic and supersonic flow of Bose condensed atoms. These setups contain at least one black hole sonic horizon from which the analog of Hawking radiation should be generated and emitted against the flow in the subsonic region. Multiple coherent scattering by the double-barrier structure strongly modulates the transmission probability of phonons, rendering it very sensitive to their frequency. As a result, resonant tunneling occurs with high probability within a few narrow frequency intervals. This gives rise to highly non-thermal spectra with sharp peaks. Even at achievable nonzero temperatures, we find that the radiation peaks can be dominated by the spontaneous emission, i.e. enhanced zero-point fluctuations, and not, as often in analog models, by stimulated emission.

II.43 Spin-orbit coupled bosons superfluid

Hui Zhai
Institute for Advanced Study, Tsinghua University

Recently, spin-orbit coupled boson condensate has been realized in NIST experiment, and there are many proposals to generate various types of spin-orbit coupling in cold atom setup. I will present our theoretical results about ground state and finite temperature properties of spin-orbit coupled interacting bosons. At zero temperature this system exhibits two different phases, the plane wave phase and the stripe phase. At finite temperature, melting of stripe order gives rise to a novel phase, i.e. boson paired superfluid which supports fractionalized vortices. I shall present the phase diagram of this system in terms of temperature, interaction and anisotropy of spin-orbit coupling. Moreover, I will discuss collective modes, vortices and the response to optical lattices of spin-orbit coupled superfluids;

Ref. 1. Chunji Wang, Chao Gao, Chao-Ming Jian and Hui Zhai, Physical Review Letters, 105, 160403 (2010)
2. Chao-Ming Jian and Hui Zhai, to be submitted

III.1 TBA

Alain Aspect
Laboratoire Charles Fabry, Institut d'Optique, Palaiseau, France

III.2 Monte Carlo study of quantum phase diagram of Rydberg atoms with repulsive 1/r6 interaction

O. N. Osychenko1, G. E. Astrakharchik1, Y. Lutsyshyn2, Yu. E. Lozovik3, and J. Boronat1
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2) Institut für Physik, Universität Rostock, 18051 Rostock, Germany 3) Institute of Spectroscopy, 142190 Troitsk, Moscow regio

We study the quantum phase diagram of bosons interacting via repulsive van der Waals 1/r6 potential. The critical density for zero temperature gas-crystal phase transition is obtained from diffusion Monte Carlo calculations. Quantum phase transition at finite temperature is located in path integral Monte Carlo calculations. In high-temperature classical regime the critical temperature is quadratic with density as obtained in classical Monte Carlo simulations. Harmonic theory of classical crystal is used to draw the transition line for a given value of the Lindemann parameter.

III.3 Supersolid Phases in Imbalanced Atomic Fermi Mixtures

Jildou Baarsma and Henk Stoof
ITP Utrecht

In the phase diagram of a two-component Fermi mixture of 6Li and 40K atoms, we recently showed a Lifshitz point to be present, which signals an instability towards a supersolid phase. A supersolid occurs in a Fermi mixture when a space-dependent pairing field, the order parameter describing the Cooper pairs, is more favorable than a constant pairing field, as the usual homogeneous BCS superfluid has. To study the supersolid phase in detail we therefore incorporated the possibility of a space-dependent pairing field into BCS theory.
We were able to complete the phase diagram for a mixture of 6Li and 40K atoms. We find the phase transition from the normal gas of fermionic atoms to a supersolid state to be continuous, i.e., of second order. We find that near the Lifshitz point the supersolid phase is of the Larkin-Ovchinnikov type, which is the simplest example of a supersolid. For larger population imbalances a phase transition occurs to a supersolid state with more broken spatial symmetries.

III.4 Stability and many-body effects in dipolar mono- and bilayer fermionic systems

A. Micheli, S. Ronen, L. Sieberer, M. Baranov and P. Zoller
Institute for Theoretical Physics, University of Innsbruck

We discuss stability, collective modes and BCS pairing in a quasi-two-dimensional single component gas of polarized fermionic dipoles (monolayer) and in a coupled system of two such gases (bilayer). These experimentally realizable systems demonstrate very unusual behavior of the collective modes in the normal phase, as well as provide a variety of possibilities for both conventional and unconventional BCS pairing including a specific two-dimensional version of the BCS-BEC crossover.

III.5 Universal Relations for Atoms with Large Scattering Length

Eric Braaten
Ohio State University

The behavior of atoms with a large scattering length is constrained by universal relations that hold for any state of the system. These relations involve a central property of the system called the contact, which measures the number of pairs of atoms that have small separations. The contact controls the thermodynamics of the system as well as the large-momentum and high-frequency tails of correlation functions. This review summarizes the current theoretical and experimental status of these universal relations.

III.6 Exploring the physics of disorder with a tunable Bose-Einstein condensate

C. D'Errico, E. Lucioni, L. Tanzi, B. Deissler, M. Moratti, M. Modugno, M. Inguscio, G. Modugno
LENS - University of Florence

The combination of disorder and nonlinearities determines the transport properties of many physical systems, including normal conductors and superconductors, biological systems, or light in disordered nonlinear media. While a full understanding of the interplay of disorder and nonlinearities has long been sought, the lack of complete control over experimental parameters in most systems makes systematic investigations difficult, and there are still several open questions. I will describe how in recent experiments we have employed Bose-Einstein condensates with tunable interactions in combination with optical potentials to address some of the open questions, related for example to the transport properties and to the transition from insulating to superfluid phases. In particular, we have observed the crossover from an Anderson insulator to a BEC induced by a repulsive interaction by studying the momentum distribution and the correlation function. In addition, we have characterized the subdiffusive transport...

III.7 Cavity-mediated long-range interactions in a dilute quantum gas

Tobias Donner, Ferdinand Brennecke, Rafae Mottl, Kristian Baumann, Renate Landig and Tilman Esslinger
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We create a Bose-Einstein condensate with long-range atom-atom interactions which are mediated by the vacuum field of an optical cavity. These long-range interactions lead to a phase transition (equivalent to the Dicke quantum phase transition) between a normal and a self-organized phase, where the atoms arrange on a checkerboard lattice. We study the system in proximity to this phase transition and observe a roton-type mode softening in the Bogoliubov spectrum, accompanied by an increased susceptibility of the system to external perturbations.

Photons leaking out of the cavity give us real-time access to the dynamics of atomic density fluctuations. We observe a dramatic increase of these fluctuations when approaching the phase transition together with a critical slow down of their dynamics. We apply quantum Langevin formalism to model this behavior and identify a regime which is dominated by quantum fluctuations. These are significantly larger due to the open character of the system.

III.8 Remote Entanglement between a Single Atom and a Bose-Einstein Condensate
M. Lettner, M. Mücke, S. Riedl, C. Vo, C. Hahn, S. Baur, J. Bochmann, S. Ritter, S. Dürr, G. Rempe
MPQ

Entanglement between stationary systems at remote locations is a key resource for quantum networks. We report on the experimental generation of remote entanglement between a single atom inside an optical cavity and a Bose-Einstein condensate (BEC) [1]. To produce this, a single photon is created in the atom-cavity system, thereby generating atom-photon entanglement. The photon is transported to the BEC and converted into a collective excitation in the BEC, thus establishing matter-matter entanglement. After a variable delay, this entanglement is converted into photon-photon entanglement. The matter-matter entanglement lifetime of 0.1 ms exceeds the photon duration by two orders of magnitude. The total fidelity of all concatenated operations is 95%. This hybrid system opens up promising perspectives in the field of quantum information.
[1] M. Lettner et al., PRL (in press), arXiv:1102.4285.

III.9 High sensitivity trapped Atom Interferometry with Bose Einstein Condensates
Marco Fattori
CNR - LENS
In this paper we will describe the preliminary stages of the construction of a Mach-Zehnder spatial interferometer operating with trapped BECs, which aims at competing with state-of-the-art interferometers with cold (non condensed) atomic gases. We will describe how we plan to suppress interaction induced decoherence using Feshbach resonances and how to produce ultra-stable optical potentials for the coherent manipulation of atoms. Entangled states will be used to improve the sensitivity of the sensor beyond the standard quantum limit to ideally reach the ultimate Heisenberg limit set by quantum mechanics.

III.10 New results on Efimov physics and the creation of RbCs molecules
F. Ferlaino, M. Berninger, A. Zenesini, B. Huang, S. Besler, T. Takekoshi, M. Debatin, R. Rameshan, L. Reichsöllner, H.-C. Nägerl, and R. Grimm
Institute of Experimental Physics, University of Innsbruck, Austria

We present new results from two different experiments on ultracold gases.
In a first experiment, we investigate universal few-body physics across different Feshbach resonances with ultracold cesium atoms. Surprisingly we observe five distinct Efimov resonances in a magnetic field range up to 1000G, which all occur at the same value of the scattering length. This result points to universality across all Feshbach resonances and rules out a significant variation of the three-body parameter. New results on five-body physics will also be presented.
In a second experiment, we produce a degenerate ultracold mixture of 87Rb and 133Cs atoms. We investigate the interspecies scattering properties by Feshbach spectroscopy. Starting with magneto-associated Feshbach molecules, we perform spectroscopic measurements on the two-photon optical transition that will serve to transfer RbCs molecules to the rovibronic ground state via a STIRAP transfer scheme.

III.11 Solitons as the Early Stage of Quasicondensate Formation during Evaporative Cooling

E. Witkowska, P. Deuar. M. Gajda, and K. Rzazewski
Institute of Physics, PAN

We study the evaporative cooling dynamics of trapped one-dimensional Bose-Einstein condensates for parameters leading to a range of condensates and quasicondensates in the final equilibrium state, using the classical fields method. We confirm that solitons are created during the evaporation process by the Kibble-Zurek mechanism, but subsequently dissipate during thermalization. However, their signature remains in the phase coherence length, which is approximately conserved during dissipation in this system.

References:
E. Witkowska, P. Deuar. M. Gajda, and K. Rzazewski, Phys. Rev. Lett. 106, 135301 (2011)

III.12 Two-Photon-Spectroscopy of YbRb - Towards paramagnetic molecules

Frank Münchow, Cristian Bruni, Maximilian Madalinski, Axel Görlitz
University of Düsseldorf

Due to its paramagnetic ground state YbRb is a candidate for the realization for the realization of lattice-spin models with dipolar molecules. Here we report on the first spectroscopic investigation of vibrational levels in the electronic ground state ^{176}Y^{87}Rb. Using two-photon photoassociation spectroscopy in a laser-cooled mixture of ^{176}Yb and ^{87}Rb we are able to determine the binding energies of weakly-bound vibrational levels. This is an important step towards the realization of YbRb ground state moelcules.

III.13 Atomic Einstein-Podolsky-Rosen entanglement detected by homodyning of matter wave fields.

C. Gross, H. Strobel, E. Nicklas, T. Zibold, N. Bar-Gill, G. Kurizki, M.K. Oberthaler
University of Heidelberg

For light Einstein-Podolsky-Rosen entanglement has been observed already 20 years ago. In atomic systems, however, this famous kind of continuous variable entanglement eluded its generation and detection, also, due to the lack of a suitable measurement technique. We report on the implementation of this technique – homodyne detection of atomic fields – and use it to detect Einstein-Podolsky-Rosen entangled atomic quantum states. The quantum correlations are generated in a Bose-Einstein condensate employing twin-atom production via spin changing collisions and detected using the Einstein-Podolsky-Rosen entanglement criterion for the atom number difference and the sum-phase.

III.14 Phase-slips and the self-trapping regime of a bosonic Josephson junction

M. Guilleumas, M. Abad, R. Mayol, M. Pi and D.M. Jezek
Universitat de Barcelona

A dipolar condensate confined in a toroidal trap constitutes a self-induced Josephson junction when the dipoles are oriented perpendicularly to the trap symmetry axis and the s-wave scattering length is small enough. The ring-shaped double-well potential coming from the anisotropic character of the mean-field dipolar interaction is robust enough to sustain a self-trapping dynamics, which takes place when the initial population imbalance between the two wells is large. We show that in this system the self-trapping regime is directly related to a vortex-induced phase-slip dynamics. Two vortices are spontaneously nucleated in the low density regions before a minimum of the population imbalance is reached. Then, both vortices cross the toroidal section in opposite directions, through the junctions, yielding a 2π phase slip between the two weakly linked condensates and causing thus the inversion of the particle flux between the two wells.

III.15 Hall conductivity of lattice bosons or "What is a hole condensate?"

Sebastian Huber, Netanel Lindner
Weizmann Institute of Science, Caltech

In a moving superfluid a force acts on a vortex similar to the Magnus force acting on a spinning football. In the absence of disorder, the resulting vortex velocity has to be parallel to the motion of the superfluid. The direction, with or against the flow, and the speed of the vortex is only fixed in a Galilean invariant system, however. Here, we discuss a general setup of interacting lattice-bosons and map out a phase diagram for the behavior of the vortex. We find that the strongly interacting superfluid is characterized by a topological index. Our findings have a clear experimental signature and we show how it gives rise to a unambiguous definition of what a bosonic "hole condensate" is.

III.16 Stability of spin-orbit coupled Fermi gases with population imbalance

M. Iskin, A. L. Subasi
Koc University

We use the self-consistent mean-field theory to analyze the effects of Rashba-type spin-orbit coupling (SOC) on the ground-state phase diagram of population-imbalanced Fermi gases throughout the BCS-BEC evolution. We find that the SOC and population imbalance are counteracting, and that this competition tends to stabilize the uniform superfluid phase against the phase separation. However, we also show that the SOC stabilizes (destabilizes) the uniform superfluid phase against the normal phase for low (high) population imbalances. In addition, we find topological quantum phase transitions associated with the appearance of momentum space regions with zero quasiparticle energies, and study their signatures in the momentum distribution.

III.17 Atom-atom interaction in line-centered optical lattices

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Recently a line-centered optical lattice has been proposed and analyzed for cold atoms [1]. The dispersion of such a lattice contains a Dirac cone intersecting with a completely flat band [1]. Here we analyze effects due to the atom-atom interaction of the Hubbard type for the line-centered lattice. The lattice is filled with fermionic atoms in two different internal states A and B. The Hubbard interaction takes place between the A and B state atoms populating the same lattice sites. We have identified localized eigen-states of the non-interacting Hamiltonian, which are immune to the atom-atom interaction and constitute a half of the flat band. Thus there is a cost in energy due to the atom-atom interaction to place an extra B atom in the flat band half-filled with the A atoms. However for smaller filling factors of the A atoms there is no energy cost to add a B atom. This leads to a jump in the chemical potential at the half-filled flat band.
[1] R. Shen et al. Phys. Rev. B 81, 041410 (2010).

III.18 Spin dynamics of a fragmented spinor BEC

Yuki Kawaguchi and Masahito Ueda

University of Tokyo

We investigate the spin dynamics starting from and toward a fragmented Bose-Einstein condensate (BEC) of spin-1 and spin-2 atoms. The many-body ground state of a spinor BEC is known to be fragmented when the spin-exchange interaction is not ferromagnetic: condensation of a spin-singlet pair or a spin-singlet trimer occurs. We point out that the Goldstone modes in the Bogoliubov spectrum of a single condensate, i.e., a mean-field ground state, naturally include the instability towards the fragmented ground state. In the presentation, we will show the decoherence dynamics of a single condensate. On the other hand, when the spin-exchange interaction is ferromagnetic, the fragmented BEC is unstable. We compare the dynamics starting from fragmented and single BECs with zero magnetization, and find that the time evolution of the growth of the magnetization is different for two cases. Our result suggests that the fragmented BEC is distinguishable from an ensemble of single BECs with random phases in experiments.

III.19 Bose-Einstein condensate of Calcium-40

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Alkaline earth atoms offer unique properties due to their non degenerate ground state and their extremely narrow intercombination transitions.
We condense 2x10^4 40Ca atoms in both a single- and a crosed-beam optical trap in 3s. Due to large three body losses an optimized loading and cooling scheme is necessary.
To excite the ultracold atoms on the 1S0–3P1 intercombination transition a 1 Hz linewidth diode laser is used. Optical Feshbach resonances (OFR) using molecular states near the 1S0–3P1 asymptote promise to have low inelastic losses. These OFR can be used to modify the scattering length on small length scales and thus e.g. to produce a periodic or even a disordered potential. As a first step we use photoassociation spectroscopy to search for bound molecular states near the 1S0–3P1 asymptote.
On the other hand, by exciting the atoms on resonance we investigate the loss of coherence by collisions as a first step towards investigation of superradiant decay of the metastable state.

III.20 Optical Feshbach Resonances in BECs and Novel Quantum Degenerate Fermi Gases of Atomic Strontium

Mi Yan, Brian DeSalvo, and Thomas C. Killian
Rice University, Department of Physics and Astronomy

We will describe experiments with Bose-Einstein condensates of 88Sr and quantum degenerate Fermi gases of 87Sr. 88Sr has a small negative scattering length leading to a maximum condensate size for our trapping conditions of about 104 atoms. The small scattering length makes it very sensitive to changes in interaction length induced by an optical Feshbach resonance (OFR). We will discuss our control of collapse and expansion of the condensate with an OFR and prospects for using this tool for other experiments with strontium quantum fluids. Degenerate Fermi gases of alkaline earth metal atoms open new possibilities in the study of many-body physics because of the existence of isotopes with large nuclear spin I (e.g. I=9/2 in 87Sr), which gives rise to a large SU(N=2I+1) symmetry of the Hamiltonian. We will describe the manipulation and probing of spins in this system and progress towards putting quantum degenerate 87Sr in an optical lattice.

III.21 Guided atom laser interacting with complex potentials

R. Mathevet, P. Cheiney, F. Vermersch, C. M. Fabre, G.L. Gattobigio, T. Lahaye and D. Guery-Odelin
Universite Paul Sabatier/CNRS

A guided atom laser is extracted from a BEC in the horizontal beam of the crossed dipole trap in which it was created. Interaction with a second laser beam or standing wave is discussed.

III.22 Observation of a “blue” potassium MOT at 405nm

D. McKay, D. Jervis, D. Fine, G. Edge and J. Thywissen
University of Toronto

We report on the observation of a “blue” potassium MOT on the 4S to 5P open transition at 404.53nm for two isotopes (K-41 and K-40). First we load atoms using a standard “red” (767nm) MOT and then we pulse on the blue MOT for approximation 20ms. We are able to load all the atoms into the blue MOT and observe that the density increases and the temperature decreases because of the narrower linewidth of the 4S-5P transition. This increased phase-space density will help to achieve degeneracy of fermionic K-40. Ultimately we are working towards in-situ imaging of K-40 in an optical lattice to probe Fermi-Hubbard physics. Imaging will be facilitated by collecting the fluorescence from Doppler cooling using the same blue transition used for the MOT. Compared to imaging with 767nm Doppler cooling, the smaller wavelength will increase the resolution and the lower temperature will reduce the constraints on lattice height. Our laser system consists of a grating-stabilized master laser with 10m...

III.23 Characterisation of the multi-branch excitation spectrum of a strongly correlated superfluid

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BEC-INO-CNR and Dipartimento di Fisica, Trento

We investigate the nature of the excitation modes along the superfluid to Mott insulator transition. In previous works, it has been established that, before becoming gapped at the transition point, the excitation spectrum develops a multi-mode structure in the regime of strongly correlated superfluid. Applying the random phase approximation, we calculate the spectral weights of spectral function and structure factor and determine the particle and density character of the different branches. We show that by increasing the correlations in the superfluid phase, an anti-crossing of excitation modes close to the Brilloun zone boundary leads to an hibridization of the modes, so that both lowest branches acquire a non negligible density character. This implies that the multi-mode structure in the strongly correlated superfluid should be observable not only in lattice modulation experiments, but also in the measurement of the structure factor.

III.24 Macroscopic superpositions by nonadiabatic stirring of a Tonks-Girardeau gas on a quasi-1D ring

Anna Minguzzi, Christoph Schenke, Frank W. Hekking
Universite Grenoble I, CNRS, Laboratoire de Physique et Modelisation des Milieux Condenses, BP 166, Grenoble FRANCE

Strongly correlated quasi-onedimensional bosons on a ring are promising candidates for the realization of macroscopic superpositions of angular momentum states, with potential applications to high-precision atomic gyroscopes. We focus on the impenetrable-boson (Tonks-Girardeau) limit, where we use the time-dependent Bose-Fermi mapping to provide an exact analytical solution for the dynamical evolution of the many-body wavefunction following a sudden set into rotation of a localized barrier potential. As a result of the time evolution, we find the formation of a macroscopic superposition of two angular momentum states, which can be fully characterized by our microscopic analysis. In particular, we show that the barrier velocity should be tuned sufficiently close to multiples of the half-integer Coriolis flux to maximize the nonadiabatic excitation and should be larger than the sound velocity to discriminate the two components of the superposition.

III.25 Adiabaticity timescales in optical lattices

Stefan Natu and Erich Mueller
Cornell University

We study the timescales for adiabaticity of trapped cold bosons subject to a time-varying lattice potential using a dynamic Gutzwiller mean-ï¬eld theory. We explain apparently contradictory experimental observations by demonstrating a clear separation of timescales for local dynamics (∼ms) and global mass redistribution (∼ 1s). We provide a simple explanation for the short and fast timescales finding that while density/energy transport is dominated by low energy phonons, particle-hole excitations set the adiabaticity time for fast ramps. We show how mass transport shuts oï¬€ within Mott domains, leading to a chemical potential gradient that fails to equilibrate on experimental timescales.

III.26 Disorder in spin-1 Bose Hubbard Model

S. Paganelli, M. Lacki, V. Ahufinger, A. Sanpera, J. Zakrzewski
UAB

We illustrate the zero temperature phase diagram of the spin 1 BH model in a 2D square lattice in the presence of disorder using a mean field Gutzwiller ansatz and a stochastic mean field approximation. We focus on the antiferromagnetic case and we study three different types of disorder: in the chemical potential, in the spinor interaction and in the spinless interaction coupling. In the presence of disorder in the chemical potential, we obtain that MI lobes with odd occupation disappear and the emergence of the Bose glass (BG) phase between MI lobes with even occupancy occurs.
For large enough spinor coupling, when the disappearance of the lobes with odd occupancy occurs already in the absence of disorder, a BG of singlets is predicted. Adding disorder in the spinor coupling, we observe that the BG phase appears only between lobes corresponding to n and $n+1$ occupations with n-odd.

III.27 An Atom-Chip Apparatus for Lightless Artificial Gauge Fields

A. R. Perry, K. Jimenez Garcia, R. A. Williams, L. J. LeBlanc, M. C. Beeler, I. B. Spielman
Joint Quantum Institute, National Institute of Standards and Technology, and the University of Maryland

Experiments creating artificial gauge fields using ultracold atoms have demonstrated both artificial magnetic fields and now spin-orbit coupling [1,2] in 87Rb Bose-Einstein condensates (BECs). However this previous approach is limited by spontaneous emission, and restricts studies of the quantum Hall limit of bosons, non-Abelian gauge fields, and fermionic systems [3]. We report on the construction of a new atom-chip apparatus for the study of artificial gauge fields in 87Rb BECs, and later 40K Fermi systems. The new atom-chip apparatus will replace the effective magnetic field from Raman laser beams (vector light shifts) with the real magnetic field from “Raman wires” on an atom-chip, effectively eliminating spontaneous emission. This atom-chip design represents a significant step towards realizing time-reversal invariant topological insulators in ultracold gases [3]. [1]Y.-J. Lin et al., Nature, 462 628(2009) [2]Y.-J. Lin et al., Nature 471, 83-86(2011) [3]N. Goldman et al, PRL 105 255302(2010)

III.28 Analytical approach to Bose-Einstein condensates on slightly biased double-well potentials

A. Polls, B. Julia-Diaz, M. Mele-Messeguer, J. Martorell
University Barcelona

An analytical insight into the symmetry-breaking mechanism underlying the transition from Josephson to self-trapping regimes in Bose-Einsteins condensates is presented. We provide expressions for the ground-state properties of a Bose gas with attractive interactions modeled by a two-site Bose-Hubbard Hamiltonian with an external bias. Simple formulas are found relating the appearance of fragmentation in the condensate with the large quantum fluctuations of the population imbalance which take place in the transition from Josephson to the self-trapped regime. The formalism is finally extended to Bose mixtures where genuine mixture phenomena are identified.

B. Julia-Diaz, J. Martorell and A. Polls, Phys. Rev. A81,003600 (2010).
M. Mele-Messeguer, B.Julia-Diaz, M. Guilleumas, A. Polls, A. Sanpera, New Jour. Phys. 13, 0033012 (2011)

III.29 Many- body phases of dipolar gases

G. Pupillo, M. Dalmonte, F. Cinti, P. Jain, M. Boninsegni, P. Zoller
IQOQI, Austrian Academy of Sciences

We present results for exotic phases of dipolar gases trapped in optical lattices: stable trimer liquids and crystals of polar molecules in coupled wires, and a free-space supersolid with Rydberg atoms.

III.30 Selforganization and sympathetic cooling of multispecies ensembles in a cavity

Helmut Ritsch, Tobias Griesser, Wolfgang Niedenzu
Universität Innsbruck

We predict concurrent selforganization and cooling of mixed ensembles of polarizable particles with different masses and temperatures through collective scattering of a strong pump laser into a high-Q cavity mode. Adding extra particles of any temperature lowers the minimal pump power required for selfordering into a common periodic pattern. This allows to trap one atomic species, for which high phase space densities are readily available, in combination with any other kind of atoms, molecules or even nanoparticles of up to wavelength size. Collectively enhanced scattering leads to combined trapping without any direct collisional interactions. Using a kinetic theory we calculate the threshold condition, energy fluxes and the resulting equilibrium phase space distributions. Cavity-mediated energy transfer enhances cooling of heavy particles by adding light particles forming a cold reservoir.

III.31 Correlated Rydberg ensembles in a dense atomic gas

M. Robert-de-Saint-Vincent, A. Faber, C. Hofmann, G. Günter, H. Schempp, H. Busche, S. Whitlock and M. Weidemüller
Physikalisches Institut der Universität Heidelberg

Neutral atoms in Rydberg states are highly-polarisable particles, which can experience quantum effects and interactions over macroscopic distances. Many-body systems of Rydberg atoms offer a unique opportunity to create and investigate strong correlations in atomic gases [1]. Here, we present a new experiment allowing for the production of ensembles of Rydberg atoms immersed in a Bose-Einstein condensate. We discuss the loading of a three-beam crossed dipole trap, and present first experiments on Rydberg excitation in the trapped gas. Single-atom-sensitive Rydberg-detection will then be used to probe the appearance of strongly-correlated phases. In particular, the emergence of crystalline order in the excited, interacting gas is at the center of growing interest [2,3]. These studies will ultimately form a new platform for the generation of non-classical states of matter.

[1] Schempp et al., PRL 104, 173602 (2010)
[2] Pohl et al., PRL 104, 043002 (2010)
[3] Schachenmayer et al., NJP 12, 103044 (2010)

III.32 Solitons in rapidly cooled1D Bose gas

E. Witkowska, P. Deuar, M. Gajda, and K. Rzazewski

We calculate the evaporative cooling dynamics of trapped one-dimensional Bose-Einstein condensates for parameters leading to a range of condensates and quasicondensates in the final equilibrium state, using the classical fields method. We confirm that solitons are created during the evaporation process by the Kibble-Zurek mechanism, but subsequently dissipate during thermalization. However, their signature remains in the phase coherence length, which is approximately conserved during dissipation in this system.

III.33 Anomalous diffusion of cold atoms in a 1D damped lattice

Yoav Sagi, Miri Brook, Ido Almog and Nir Davidson
Weizmann Institute of Science

We study experimentally the anomalous diffusion of cold atoms in one dimension. The ultra-cold atoms continuously scatter photons from a lattice which is in a configuration identical to the one used in the well-known Sisyphus cooling scheme. This produces a steady-state atomic velocity distribution which is a power law, with an exponent that depends on the lattice depth [1]. We image the atomic density distribution after a varying waiting time. The width of the atomic cloud exhibits a power law time dependence, and we extract its characteristic exponent for various lattice depths. We also show that the density distribution at different times is self-similar with the same characteristic exponent, in accordance with the predictions of a fractional diffusion equation [2].

[1] P. Douglas, S. Bergamini, and F. Renzoni, Phys. Rev. Lett. 96, 110601 (2006).
[2] R. Metzler and J. Klafter, Physics Reports 339, 1 (2000).

III.34 Tunneling Mechanisms in Strongly Correlated Bosonic Systems

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Quantum tunneling is an important dynamical process in ultracold many-body systems subjected to complex trapping environments such as optical lattices. The competition of the tunable interactions and the geometry of the external trap leads to a plethora of different tunneling scenarios. Paradigm examples are the self-trapping and correlated pair tunneling of repulsively interacting bosons and, for stronger interactions, to independent fermion tunneling in a single dimension. We use exact ab initio methods, such as the Multi-Configuration Time-Dependent Hartree Method, to study novel tunneling scenarios and mechanisms for pure and mixed bosonic systems. Windows of enhanced tunneling in a regime of general suppression of tunneling can be opened in the strong interaction regime by higher band contributions in multi-well traps. The resulting process of interband tunneling is identified and shown to comprise single-boson tunneling, two-boson correlated tunneling and conditional tunneling processes in general. For mixtures one species creates an effective potential for the second species, and an induced attraction leading to attractive pair tunneling is found.The latter leads to fermionic pair dynamics in the strong interaction regime. Interaction inhomogeneities in the regime of strong correlations are shown to create a plethora of novel tunneling resonances.

III.35 Out-of-Equilibrium dynamics and transport in optical lattices

Ulrich Schneider, Jens Philipp Ronzheimer, Simon Braun, Lucia Hackermüller, Sebastian Will, Tim Rom, Michael Schreiber, Immanuel Bloch
LMU München, MPQ München

The last years have seen dramatic progress in the control of quantum gases in optical lattices using both bosonic and fermionic gases as well as Bose-Fermi mixtures. It has become possible to simulate models of strongly interacting quantum particles on a lattice, for which the Hubbard model is probably the most important example.
A major advantage of these systems compared to real solids is the possibility to change all relevant parameters in real-time by e.g. varying laser intensities or magnetic fields.
By using a blue-detuned lattice in combination with a red-detuned dipole trap it was possible for the first time to create a homogeneous optical lattice without any additional potentials in 2D.
We will present new measurements concerning the out-of-equilibrium dynamics and transport properties in a homogeneous Hubbard model using both bosonic and fermionic quantum gases as well as Bose-Fermi mixtures.

III.36 TBA

Tobias Tiecke
Harvard University

III.37 Quantum Criticality from in-situ Density Imaging

Shiang Fang, Chia-Min Chung, Ping Nang Ma, Pochung Chen, Daw-Wei Wang
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We perform large-scale Quantum Monte Carlo (QMC) simulations for strongly interacting bosons in a 2D optical lattice trap, and confirm an excellent agreement with the benchmarking in-situ density measurements by the Chicago group [1]. We further present a general finite temperature phase diagram both for the uniform and the trapped systems, demonstrating how the universal scaling properties near the superfluid(SF)-to-Mott insulator(MI) transition can be observed from the in-situ density profile. The characteristic temperature to find such quantum criticality is estimated to be of the order of the single-particle bandwidth, which should be achievable in the present experiments. Finally, we examine the validity regime of the local fluctuation-dissipation theorem (FDT), which can be a used as a thermometry in the strongly interacting regime.

III.38 Controlling spin motion and interactions in a 1D Bose gas

N.J..van Druten

Van der Waals-Zeeman Institute for Experimental Physics
Universiteit van Amsterdam

III.39 Quantum simulation of frustrated magnetism on a triangular optical lattice
J. Struck, C. Oelschlaeger, R. Le Targat, P. Soltan-Panahi, M. Weinberg, C. Staarmann, J. Simonet, D. Luehmann, P. Windpassinger, K. Sengstock
Institut fuer Laserphysik, Universitaet Hamburg

We have realized a quantum simulator for magnetism with scalar bosons in a triangular optical lattice. To this end, we identify the local superfluid phase with a classical spin. By tuning the tunneling matrix elements between neighboring lattice sites in magnitude and sign, we can emulate a large variety of magnetic phases in this lattice geometry. We could confirm all the expected magnetic phases, ranging from ferromagnetic via parallel- and staggered-spin-chains to mixed anitferromagnetic-ferromagnetic phases and fully antiferromagneitc systems. In the latter case, we could even observe spin frustration which leads to spontaneous symmetry breaking.
We will present the experimental results obtained for the relevant regions of the spin-phase diagram together with a discussion on the technical realization of the spin-emulator. These results open the perspective to extremely complex and yet not well understood phases like the spinliquid in a quantum xy-model.

III.40 Superfluidity and Anomalous Correlations in a Two-Dimensional Bose Gas
Tod M. Wright, Christopher J. Foster, and Matthew J. Davis
University of Queensland

The relationship between superfluidity, Bose condensation, and the Berezinskii-Kosterlitz-Thouless (BKT) phase transition in finite-size quasi-two-dimensional Bose gases has been the source of some confusion in experimental and theoretical investigations in recent years. Here we use a classical-field method to demonstrate that the transition to a superfluid quasicondensate in a finite-sized 2D homogeneous Bose gas is associated with the emergence of an underlying Bose condensate, as evidenced by the appearance of anomalous ("symmetry-broken") correlations in the gas. We consider dynamical aspects of the 2D Bose field, and calculate dynamic density and phase structure factors of the system. These correlations further elucidate the character of the superfluid transition, and the nature of the pre-superfluid phase immediately above the BKT transition.

We apply our findings to the non-equilibrium dynamics of a metastable superflow in a quasi-two-dimensional toroid in the presence of a non-rot...

III.41 Memory of the initial conditions and dynamics of incomplete relaxation
in a quantum cold-atomic system
V. A. Yurovsky (1), A. Ben-Reuven (1), M. Olshanii (2)
(1) School of Chemistry, Tel Aviv University, (2) Department of Physics, University of Massachusetts Boston

We show that in a quantum system with no selection rules, the expectation value of a generic observable after relaxation is given by a linear interpolation between its initial and thermal expectation values. The variable of this interpolation is universal, and this simple law covers the whole spectrum of the chaotic behavior, from the integrable regime through the well-developed quantum chaos [V. A. Yurovsky and M. Olshanii, Phys. Rev. Lett. 106, 025303 (2011)].
These predictions are confirmed for two zero-range-interacting atoms in a

circular, transversely harmonic, multimode waveguide. Relaxation of this system demonstrates non-exponential behavior and fluctuations. The relaxation time scales inversely-proportionally to the density of states. The fluctuation amplitude scales inversely-proportionally to the square root of the number of eigenstates in the initial state.

III. 42 Extraction of information from dynamics for strongly correlated systems/Disorder for spinor condensates in optical lattices

M. Lacki, D. Delande, and J. Zakrzewski
Jagiellonian University

Nonadiabatic effects in dynamics across a Quantum Phase Transition (QPT) in Bose-Hubbard model is considered both for superfluid-Mott insulator QPT and for superfluid-disordered insulator case. As found by us before [1] the nonadiabatic behavior is amplified for disordered systems. We have developed recently a novel approach enabling us to extract the excited states significantly populated during the quench through the QPT from the dynamically formed (during the turn on of optical lattices) wavepacket. While previously energies of excited states were obtained, now we have an access to excited eigenstates [2] extracted from the time-dependent-block-decimation (TEBD) algorithm. The analysis of important excitations allows to introduce a neat classification of them for the mott dominated region (for system without disorder) as well as present evidence concerning Bose glass preparation in recent experiments. We discuss also possibility of observing disorder induced effects in spinor condensates in optical lat...

III.43 A trapped single ion inside a Bose-Einstein condesate

C. Zipkes, L. Ratschbacher, S. Palzer, C. Sias, M. Köhl
University of Cambridge

In recent years, improved control of the motional and internal quantum states of ultracold neutral atoms and ions has opened intriguing possibilities for quantum simulation and quantum computation. Many-body effects have been explored with hundreds of thousands of quantum-degenerate neutral atoms and coherent light-matter interfaces have been built. We are interested in how to advantageously combine such a quantum degenerate gas with a single trapped ion, to allow for local probing and manipulation. To this end, we immerse a single trapped Yb+ ion in a Bose-Einstein condensate of Rb atoms.

As a first synergetic effect we observe the sympathetic cooling of the trapped ions to very low temperatures through collisions with the ultracold neutral gas. We monitor the dynamics of this effect by measuring the mean ion energy after having an initially hot ion immersed into the condensate for various interaction times. Energy dependant scattering properties are investigated through neutral atom losses and temp...