# INDEX

## KEYNOTES TALKS

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>G. Rempe</td>
<td>Exploring quantum matter with cold and ultracold molecules</td>
<td>1</td>
</tr>
<tr>
<td>Jun Ye</td>
<td>Cold and ultra cold polar molecules</td>
<td>2</td>
</tr>
<tr>
<td>F. Schreck</td>
<td>Exploring an ultracold Fermi-Fermi mixture: interspecies Feshbach resonances of 6Li-F</td>
<td>3</td>
</tr>
<tr>
<td>R. Krems</td>
<td>Cold controlled chemistry</td>
<td>4</td>
</tr>
<tr>
<td>Ch. Fort</td>
<td>Experiments with ultracold atoms in optical potentials: searching for disorder induced</td>
<td>5</td>
</tr>
<tr>
<td>K. Baldwin</td>
<td>Atom laser and atomic physics with metastable helium</td>
<td>5</td>
</tr>
</tbody>
</table>

## SHORT TALKS

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>M. Trippenbach</td>
<td>Bunching of scattered atoms in BEC collision</td>
<td>6</td>
</tr>
<tr>
<td>D. Boiron</td>
<td>Quantum degenerate gases of metastable helium atoms</td>
<td>6</td>
</tr>
<tr>
<td>D. Jaksch</td>
<td>Optical lattice immersions</td>
<td>7</td>
</tr>
<tr>
<td>N. Herschbach</td>
<td>Bosonic and fermionic metastable neon atoms in optical and magnetic traps</td>
<td>7</td>
</tr>
<tr>
<td>L. Hackermüller</td>
<td>Bose-Fermi mixtures in optical lattices</td>
<td>8</td>
</tr>
<tr>
<td>A. Daley</td>
<td>Andreev-like reflections with cold atoms</td>
<td>8</td>
</tr>
<tr>
<td>A. Marian</td>
<td>AC electric trapping of neutral atoms</td>
<td>9</td>
</tr>
<tr>
<td>M. Drewsen</td>
<td>Cold molecular ions: Single molecules experiments</td>
<td>9</td>
</tr>
<tr>
<td>M. Kowalewski</td>
<td>Ab initio based calculations of cavity cooling including the rovibrational models of the</td>
<td>10</td>
</tr>
<tr>
<td>M. Tarbut</td>
<td>Stark deceleration of cold lithium hydride molecules</td>
<td>11</td>
</tr>
<tr>
<td>T. Freegarde</td>
<td>Cavity-mediated cooling with a single mirror</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Matter wave interference and matter wave interferometry with interactions: quantum</td>
<td>12</td>
</tr>
<tr>
<td>H.C. Nägerl</td>
<td>carpets and matter wave spin echo</td>
<td>12</td>
</tr>
<tr>
<td>P. Törmä</td>
<td>Fermi gases and FFLO state in optical lattices and exact dynamics of RF-spectroscopy</td>
<td>12</td>
</tr>
<tr>
<td>R. Wester</td>
<td>Formation of ultracold LiCs molecules</td>
<td>13</td>
</tr>
<tr>
<td>A. Niederberger</td>
<td>Disorder-induced order in ultracold Fermi gases</td>
<td>13</td>
</tr>
<tr>
<td>G. Meijer</td>
<td>Molecular collision studies with Stark-decelerated beams</td>
<td>14</td>
</tr>
<tr>
<td>H.P. Büchler</td>
<td>Repulsive shield between polar molecules</td>
<td>15</td>
</tr>
<tr>
<td>J. Danzl</td>
<td>Quantum gas of deeply bound ground state molecules</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Author(s)</td>
<td>Title</td>
</tr>
<tr>
<td>---</td>
<td>--------------------</td>
<td>---------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>A. D. Lange et al.</td>
<td>Heteronuclear feshbach resonances in a mixture of ultracold 87 Rb and 133Cs</td>
</tr>
<tr>
<td>2</td>
<td>A. Fioretti et al.</td>
<td>New analysis of REMPI spectra of ultracold rubidium molecules</td>
</tr>
<tr>
<td>3</td>
<td>A. Kurcz</td>
<td>On the quantum optical heating in sonoluminescence experiments</td>
</tr>
<tr>
<td>4</td>
<td>A. Ridinger et al.</td>
<td>Towards quantum simulators with 40K-6Li Fermi mixtures</td>
</tr>
<tr>
<td>5</td>
<td>A. Vukics et al.</td>
<td>Cavity-assisted laser cooling of linearly polarisable particles - prospects of &quot;molecooling&quot;</td>
</tr>
<tr>
<td>6</td>
<td>A. Wallis et al.</td>
<td>Ultracold molecules in combined electric and magnetic fields: a new type of conical intersection</td>
</tr>
<tr>
<td>7</td>
<td>A. Xuereb et al.</td>
<td>Semiclassical theory of coherent atom cooling with single mirror</td>
</tr>
<tr>
<td>8</td>
<td>B. Rivington et al.</td>
<td>Energy levels of RbCs and KRb in the presence of external fields</td>
</tr>
<tr>
<td>9</td>
<td>C. Sommer et al.</td>
<td>Production of a continuous guided beam of slow and internally cold molecules from a cryosource</td>
</tr>
<tr>
<td>10</td>
<td>C. Trefzger et al.</td>
<td>Dipolar Bosons in a 2D optical lattice</td>
</tr>
<tr>
<td>11</td>
<td>D. Dagnino et al.</td>
<td>Broken symetry ground and excited states of small rotating bosonic and fermionic systems</td>
</tr>
<tr>
<td>12</td>
<td>D. Nagy et al.</td>
<td>Self-organization of a Bose-Einstein condensates in an optical cavity</td>
</tr>
<tr>
<td>13</td>
<td>D.J. McCarron et al.</td>
<td>Cold collisions in a 87RB - 133Cs mixture</td>
</tr>
<tr>
<td>14</td>
<td>E. Tiemann et al.</td>
<td>Cold polar molecules and molecular spectroscopy</td>
</tr>
<tr>
<td>15</td>
<td>E. Wille et al.</td>
<td>Exploring ultracold fermi-fermi mixtures: part I - overview</td>
</tr>
<tr>
<td>16</td>
<td>F. Ferlaino et al.</td>
<td>Ultracold Cesium molecules and Cs-Rb mixtures</td>
</tr>
<tr>
<td>17</td>
<td>G. Duffy et al.</td>
<td>BEC-BCS Crossover in ultracold Fermi gas: a new experimental seup</td>
</tr>
<tr>
<td>18</td>
<td>G. Hendl et al.</td>
<td>Exploring ultracold fermi-fermi mixtures: part II - Technology</td>
</tr>
<tr>
<td>19</td>
<td>G. Morigi et al.</td>
<td>Cavity cooling of molecules to the ground state</td>
</tr>
<tr>
<td>20</td>
<td>G. Pupillo et al.</td>
<td>Floating crystals and lattices of polar molecules</td>
</tr>
<tr>
<td>21</td>
<td>G. Raoati et al.</td>
<td>Towards quantum gases of polar KRb molecules</td>
</tr>
<tr>
<td>22</td>
<td>G. Szirmai et al.</td>
<td>Geometric resonance cooling of polarizable particles in a optical waveguide</td>
</tr>
<tr>
<td>23</td>
<td>G. Toth et al.</td>
<td>Optimal spin squeezing inequalities for detecting entanglement with collective measurements</td>
</tr>
<tr>
<td>24</td>
<td>G.E. Astrakharchik et al.</td>
<td>Phase diagram of low dimensional dipolar gases with transverse confinement: linear, zig-zag and multiple chains</td>
</tr>
<tr>
<td>25</td>
<td>I. Bausmerth et al.</td>
<td>Destroying superfluidity rotating a Fermi gas at unitarity</td>
</tr>
<tr>
<td>26</td>
<td>I. Bausmerth et al.</td>
<td>Effects of rotation on a Fermi Gas at Unitarity</td>
</tr>
<tr>
<td>27</td>
<td>J. Asboth et al.</td>
<td>Collective excitations and instability of an optical Lattice due to Unbalanced</td>
</tr>
<tr>
<td>28</td>
<td>J. Bateman et al.</td>
<td>Investigation of cold atoms near nano-structured surfaces</td>
</tr>
<tr>
<td>29</td>
<td>J. Deiglmayr et al.</td>
<td>Spectroscopy of ultracold LiCs molecules</td>
</tr>
<tr>
<td>30</td>
<td>J. Larson et al.</td>
<td>Instabilities of cold spinless fermions in a pumped optical resonator</td>
</tr>
<tr>
<td>31</td>
<td>J. Mur-Petit et al.</td>
<td>Microscopi description of atomic Bose-Einstein condensates in the large-gas-paraemeter region</td>
</tr>
<tr>
<td>No.</td>
<td>Author(s)</td>
<td>Title</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------------------</td>
<td>-----------------------------------------------------------------------</td>
</tr>
<tr>
<td>32</td>
<td>J. Schachenmayer et al.</td>
<td>Superfluid boson currents and long range interactions in 1D optical lattices</td>
</tr>
<tr>
<td>33</td>
<td>K.A.H. van Leeuwen et al.</td>
<td>Helium 2 3S - 1S metrology at 1557 nm</td>
</tr>
<tr>
<td>34</td>
<td>L. Consolino</td>
<td>Frequency-comb-phase locked laser sources for multiresonant spectroscopy of metastable atomic Helium around 1083nm</td>
</tr>
<tr>
<td>35</td>
<td>L. Janssen et al.</td>
<td>Quantum dynamics of OH + CH4 -&gt; H2O + CH3</td>
</tr>
<tr>
<td>36</td>
<td>L. Scharfenberg</td>
<td>Crossed beam scattering experiments using Stark decelerated beams</td>
</tr>
<tr>
<td>37</td>
<td>M. Abad et al.</td>
<td>Vortex rings in toroidal Bose-Einstein condensates</td>
</tr>
<tr>
<td>38</td>
<td>M. Cristiani et al.</td>
<td>Cold Ytterbium atoms in High-finesse optical cavities: Cavity Cooling and Collective Interactions</td>
</tr>
<tr>
<td>39</td>
<td>M. Kowalewski et al.</td>
<td>Molecular Vibrational Quantum Computing with non-Resonant Raman Quantum Gates</td>
</tr>
<tr>
<td>40</td>
<td>M. Leskinen et al.</td>
<td>RF-Spectroscopy of 1D Fermi gases in an optical lattice</td>
</tr>
<tr>
<td>41</td>
<td>M. Moreno-Cardoner et al.</td>
<td>Predicting spinor condensates dynamics from simpleprinciples</td>
</tr>
<tr>
<td>42</td>
<td>M. Motsch et al.</td>
<td>Optical experiments with cold guided molecules</td>
</tr>
<tr>
<td>43</td>
<td>M. Murphy et al.</td>
<td>Optimised particle transport via harmonic potential</td>
</tr>
<tr>
<td>44</td>
<td>M. Rodríguez et al.</td>
<td>Quantum non-demolition measurement of Fermi correlations</td>
</tr>
<tr>
<td>45</td>
<td>M. Viteau et al.</td>
<td>New results on low molecules formation</td>
</tr>
<tr>
<td>46</td>
<td>M. Zeppenfeld et al.</td>
<td>Resonator modes beyond the paraxial approximation</td>
</tr>
<tr>
<td>47</td>
<td>Marler et al.</td>
<td>Cavity QED and cavity mediated cooling using ion coulomb</td>
</tr>
<tr>
<td>48</td>
<td>N. Barberan et al.</td>
<td>Dynamical evolution of trapped rotating BEC's</td>
</tr>
<tr>
<td>49</td>
<td>O. Dulieu et al.</td>
<td>Calculation of spin-orbit, static polarizabilities, and alignment of cold polar molecules</td>
</tr>
<tr>
<td>50</td>
<td>P. S. Zuchowski et al.</td>
<td>Survey of potential energy surfaces for possible sympathetic cooling systems</td>
</tr>
<tr>
<td>51</td>
<td>P. Soldán</td>
<td>On quartet states of Li2A (A=Na,K,Rb,Cs)</td>
</tr>
<tr>
<td>52</td>
<td>R. Guérout et al.</td>
<td>Potential energy surfaces of alkali trimers</td>
</tr>
<tr>
<td>53</td>
<td>R. M. Godun et al.</td>
<td>A microscope for ultracold atoms</td>
</tr>
<tr>
<td>54</td>
<td>R. Palmer et al.</td>
<td>Fractional quantum hall effect in optical lattices</td>
</tr>
<tr>
<td>55</td>
<td>R. Walters et al.</td>
<td>Dechoereence and entanglement induced by a quantum critical spin bath</td>
</tr>
<tr>
<td>56</td>
<td>S. Al-Assam et al.</td>
<td>The quantum hall effect in optical lattices</td>
</tr>
<tr>
<td>57</td>
<td>S. Braungardt et al.</td>
<td>Fermion-andspin-counting in strongly correlated systems</td>
</tr>
<tr>
<td>58</td>
<td>S. Clark et al.</td>
<td>Finite-entanglement scaling with matrix product states: applications to the Bose-Hubbard like systems</td>
</tr>
<tr>
<td>59</td>
<td>S. Ghosal et al.</td>
<td>Stimulating the production of ultracold molecules with lase pulses</td>
</tr>
<tr>
<td>60</td>
<td>S. Pilati et al.</td>
<td>Phase diagram of a polarized fermi gas at zero temperature</td>
</tr>
<tr>
<td>61</td>
<td>T. Jelters et al.</td>
<td>Bosonic and Feromionic metastable helium near quantum degeneracy</td>
</tr>
<tr>
<td>62</td>
<td>U. Gora et al.</td>
<td>How does EOM-CCSD-R12 work?</td>
</tr>
<tr>
<td>63</td>
<td>W. Skomorowski</td>
<td>Long-range relativistic interactions between like atoms in their ground and excited states and their QED retardation</td>
</tr>
</tbody>
</table>
KEYNOTE TALKS

Exploring quantum matter with cold and ultracold molecules

Gerhard Rempe
Max-Planck Institute for Quantum Optics, Germany

Remarkable progress has been made in the ability to produce samples of cold and ultracold neutral molecules, homonuclear and heteronuclear, with and without electric dipole moment, thus opening up new possibilities for exploring quantum matter. In our laboratory, we have been able to extract the slowest molecules of dipolar gases from a thermal reservoir, guide them over long distances and trap them, all with electric fields. We have associated ultracold molecules from ultracold atoms by means of ultranarrow Feshbach resonances and have produced fermionized arrays of bosonic molecules in optical lattices. The talk reviews some of these experiments, including the realization of a universal cold molecules source operated at liquid Helium temperature and the investigation of fundamental quantum phenomena which occur when ultracold molecules are restricted to zero or one spatial dimension.
Cold and ultracold polar molecules

Jun Ye
JILA, National Institute of Standards and Technology and University of Colorado

Study of ultracold molecules promises important benefits such as novel control of chemical reactions and molecular collisions, precision measurement of fundamental physical properties, and new methods for quantum information processing and quantum simulations. We undertake two approaches aimed to produce cold, polar molecular samples. In the first approach, we work directly with ground-state polar molecules such as hydroxyl radicals (OH) or formaldehyde molecules (H₂CO). After Stark deceleration through an inhomogeneously distributed electric field, OH molecules are loaded into a magnetic trap at a density $> 10^6$ cm$^{-3}$ and temperature of $\sim 70$ mK. An important advantage of magnetically trapping OH molecules is the freedom in applying an external electric field without significantly affecting the trap dynamics. The open geometry of the trap also enables experimental studies of cold, dipolar collisions subject to an external electric field. We will report our latest work in this area. In the second approach we produce ultracold polar molecules via association of two different atoms from ultracold dual gas mixtures near quantum degeneracy. Specifically, an interspecies Feshbach resonance between bosonic $^{87}$Rb and fermionic $^{40}$K permits efficient creations of heteronuclear Feshbach molecules. Subsequent optical spectroscopy reveals promising paths to efficiently transfer populations from the weakly bound to more deeply bound states. Progress on the production of these ultracold fermionic polar molecules will be reported.
Exploring an ultracold Fermi-Fermi mixture: interspecies Feshbach resonances of $^{6}\text{Li}-^{40}\text{K}$

F. Schreck,$^1$ E. Wille,$^{1,2}$ F.M. Spiegelhalder,$^1$ G. Kerner,$^1$ D. Naik,$^1$ A. Trenkwalder,$^1$ G. Hendl,$^1$ R. Grimm,$^{1,2}$ T.G. Tiecke,$^3$ J.T.M. Walraven,$^3$ S.J.J.M.F. Kokkelmans,$^4$ E. Tiesinga,$^5$ and P.S. Julienne$^5$

$^1$Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria
$^2$Institut für Experimentalphysik und Forschungszentrum für Quantenphysik, Universität Innsbruck, 6020 Innsbruck, Austria
$^3$Van der Waals-Zeeman Institute of the University of Amsterdam, 1018 XE, The Netherlands
$^4$Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands
$^5$Joint Quantum Institute, National Institute of Standards and Technology and University of Maryland, Gaithersburg, Maryland 20899-8423, USA

We report on the observation of interspecies Feshbach resonances in an ultracold mixture of two fermionic species, $^{6}\text{Li}$ and $^{40}\text{K}$. Interpretation of the data unambiguously assigns molecular bound states to the various resonances and fully characterizes the ground-state scattering properties in any combination of spin states. Using this knowledge we hope to be able to produce $^{6}\text{Li}^{40}\text{K}$ molecules, cool them to quantum degeneracy, and study their BEC-BCS crossover.
Cold controlled chemistry

Roman Krems
Department of Chemistry, The University of British Columbia

The development of experimental techniques for controlling chemical reactions externally has long been a major research goal in chemical physics. Many ground-breaking experiments demonstrated the possibility of controlling uni-molecular reactions by laser fields. External field control of bi-molecular chemical reactions, however, remains a significant challenge. External control of bi-molecular reactions is complicated by thermal motion of molecules that randomizes molecular encounters and diminishes the effects of external fields on molecular collisions. The effects of the thermal motion can be reduced by cooling molecular gases to low temperatures. Electromagnetic fields may influence molecular collisions significantly only when the translational energy of the molecules is smaller than the perturbations due to interactions with external fields. Static magnetic and electric fields as well as off-resonant laser fields readily available in the laboratory shift molecular energy levels by up to a few Kelvin so external field control of gas-phase molecular dynamics can be most easily achieved at temperatures near or less than one Kelvin. The purpose of this talk is to demonstrate that molecular collisions at low temperatures can be effectively controlled with static and laser electromagnetic fields and discuss possible applications of external field control of molecular collisions in cold gases. I will discuss molecular collisions at both cold (~1 Kelvin) and ultracold (< 1 milliKelvin) temperatures. I will demonstrate that static electric fields can be used to tune scattering resonances in ultracold gases and modify chemical reactions of cold and ultracold molecules. I will show that superimposed electric and magnetic fields may dramatically alter collision dynamics of cold molecules in a magnetic trap and describe interactions of molecules in a microwave laser cavity. Finally, I will argue that confining the motion of molecules by laser fields to two dimensions may suppress inelastic collisions and chemical reactions at ultracold temperatures and present results indicating that inelastic collisions of confined atoms or molecules in weak electromagnetic fields may be controlled by varying the orientation of the external field axis with respect to the plane of confinement.
Experiments with ultracold atoms in optical potentials: searching for disorder induced effects

Chiara Fort
INFM-CNR

We will present recent experiments performed in Florence with the aim to study disorder induced effects using ultracold atoms in optical potentials. Our approach to the realization of a disordered potential is the implementation of a bichromatic quasi-periodic optical lattice. In particular, we will discuss the possibility to observe a Bose Glass phase with strongly interacting bosons and the perspectives to observe Anderson localization with non-interacting or weakly interacting bosons.

Atom lasers and atomic physics with metastable helium

Ken Baldwin
Deputy Director, ARC Centre of Excellence for Quantum-Atom Optics, Australian National University, Canberra

Metastable helium atoms allow high efficiency detection which has enabled the recording of high resolution images of an atom laser transverse spatial profile. We observe transverse fringes on the beam, resulting from quantum mechanical interference between atoms that start from rest at different transverse locations within the outcoupling surface [1]. At high outcoupling rates we see the emergence of unusual structure on the beam profile which is not predicted by a simple Gross-Pitaevskii model.

In a separate series of experiments using the same apparatus, we have again used the unique detection properties of metastable helium to measure the 23P1 – 1 1S0 transition rate for the first time [2]. The value of 177 + 8 s-1 agrees very well with theoretical predictions, and benchmarks the iso-electronic sequence for this transition for helium-like ions. This measurement, along with other decay processes to the helium ground state, provide a fundamental test bed for quantum electro-dynamics in this, the simplest of multi-electron atoms.


SHORT TALKS

Bunching of scattered atoms in BEC collision

Marek Trippenbach, Jan Chwedenczuk, Pawel Zin, Denis Boiron, Vanessa Leung, Aurielien Perrin and Chris Westbrook

We apply a analytical model for colliding condensates to evaluate the second-order correlation function of the field of scattered atoms. Results in the first order of perturbation theory are compared with experimental results from A. Perrin et al, Phys. Rev. Lett. 99, 150405 (2007).

Quantum degenerate gases of metastable helium atoms

D. Boiron, A. Perrin, V. Krachmalnicoff, M. Schellekens, H. Chang, V. Leung, A. Aspect, C. I. Westbrook, Laboratoire Charles Fabry de l’Institut d’Optique, CNRS, Univ Paris-Sud, Palaiseau (France)
S. Moal, M. Portier, J. Dugué, M. Leduc, C. Cohen-Tannoudji, Laboratoire Kastler-Brossel, ENS, Collège de France, Paris (France)
T. Jeltes, J. McNamara, W. Hogervorst, W. Vassen, Laser Center Vrije Universiteit, Amsterdam (The Netherlands)

Metastable $^4$He (resp. $^3$He) is the only atom where Bose-Einstein condensation (resp. Fermi sea) has been achieved in an excited internal energy level and this opens interesting new perspectives. Using photoassociation techniques, the elastic scattering length has been accurately measured and giant helium dimers produced. Their high internal energy of 20 eV allows a position-sensitive, single atom detection using micro-channel plates. We used this detector to observe and characterize the atomic bunching (anti-bunching) of thermal $^4$He ($^3$He) clouds. Using a collision between two BEC we were also able to produce and detect correlated atom pairs of opposite momenta.
Optical lattice immersions

D. Jaksch, M. Bruderer, S.R. Clark, A. Klein

We investigate the influence of a Bose-Einstein condensate (BEC) on properties of immersed impurity atoms which are trapped in an optical lattice. We show that interspecies interactions lead to dephasing of the impurities and, via BEC phonons, mediate an attractive interaction between them. This may cause impurities to aggregate in a macroscopic cluster.

We investigate the impact of the BEC on transport properties and find a crossover from coherent behavior described by an extended Hubbard model to diffusive hopping. Finally, we also show that weak attractive interspecies interactions may give rise to BEC instabilities.

Bosonic and fermionic metastable neon atoms in optical and magnetic traps

Norbert Herschbach, Wouter van Drunen, Jan Schuetz, Eva-Maria Kriener, Gerhard Birkl
Institut fuer Angewandte Physik, Technische Universitaet Darmstadt

We experimentally investigate the interactions of laser cooled metastable neon atoms in a magneto-optical trap (MOT), in magnetic traps, and optical dipole traps. For the bosonic isotopes $^{20}$Ne and $^{22}$Ne we determined the rate coefficients for inelastic collisions and the scattering lengths for atoms in the metastable $^3P_2$ state. As the next step, we succeeded in optically trapping both bosonic isotopes in the metastable $^3P_0$ state and are currently determining the two-body loss coefficients.

Recent extensions of our laser configuration allow us to stably trap for the first time the fermionic isotope $^{21}$Ne in a MOT and magnetic trap. We report on the status of these experiments.
Bose-Fermi-mixtures in optical Lattices

Lucia Hackermüller, Ulrich Schneider, Thorsten Best, Sebastian Will, Simon Braun and Immanuel Bloch

We sympathetically cool fermionic 40K and bosonic 87Rb in a plugged quadrupole trap and consequently transfer both species into an optical dipole trap. After reaching degeneracy for 87Rb and 40K we either load a single species or the cold mixture into a blue detuned optical lattice.

We present a detailed study of the coherence of the Rb wave function dependent on the interaction between K and Rb and the amount of the K admixture. Moreover we have studied the behaviour of K Feshbach molecules under the influence of blue detuned laser light. K molecules are formed in the optical dipole trap at a Feshbach resonance, the absorption of blue detuned photons leads to a bound-free transition which can be used for spectroscopy of the molecular wave function.

Andreev-like reflections with cold atoms

A. J. Daley, B. Trauzettel, and P. Zoller

Andreev-like reflections, or reflections of negative-density waves arise in the context of mesoscopic transport systems, and are predicted to occur at boundaries where leads with different interaction characteristics are connected. We propose a setup in which such reflections could be observed time-dependently with cold atoms in a 1D optical lattice, with a boundary engineered at which the interaction strength changes. Using time-dependent DMRG methods, we calculate the transport of a density excitation across this boundary for typical experimental parameters. We compare the resulting reflections with predictions from Luttinger liquid models, and observe strong Andreev-like reflections in experimentally attainable regimes.
AC electric trapping of neutral atoms

Adela Marian, Sophie Schlunk, Wieland Schöllkopf, and Gerard Meijer

We have demonstrated trapping of $3 \times 10^5$ ultracold ground-state $^{87}$Rb atoms in a macroscopic ac electric trap operated at a switching frequency of 60 Hz. Similar to trapping of ions in a Paul trap, three-dimensional confinement is achieved by switching between two saddle-point configurations of the electric field. For the first time, this dynamic confinement is directly visualized with absorption images taken at different phases of the ac switching cycle. At the meeting I will present our latest studies on the electrically trapped atoms and discuss the prospects of sympathetic cooling of molecules with ultracold atoms using spatially overlapped traps.

Cold molecular ions: Single molecule experiments

Michael Drewsen

In ion traps, the translational motion of molecular ions can effectively be sympathetically cooled to temperature in the mK regime through the Coulomb interaction with laser cooled atomic ions. At such low temperatures the molecular ions typically become part of spatial ordered structures, often referred to as Coulomb crystals. The strong Coulomb interaction between trapped molecular ions and laser cooled atomic ion species makes it even possible to conduct experiments using only a single molecular ion. In the presentation, the focus will be on recent single molecule experiments as well as discuss future directions towards internal state preparation of translational cold molecular ions.
Ab initio based calculations of cavity cooling including the rovibrational modes of the OH and the NO radical

Markus Kowalewski\textsuperscript{1}, Giovanna Morigi\textsuperscript{2}, Pepijn WH. Pinkse\textsuperscript{3} and Regina de Vivie-Riedle\textsuperscript{1}

\textsuperscript{1}LMU Department Chemie, Butenandt-Str. 11, 81377 München, Germany.
\textsuperscript{2}Departament de Física, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Spain.
\textsuperscript{3}Max-Planck-Institut für Quantenoptik, Hans-Kopfermann Str. 1, D-85748 Garching, Germany.

Ultracold molecules are interesting for the study of cold chemistry, cold collisions, astrochemistry and quantum information processing. Their preparation, in particular of ultracold ground state molecules, however, is still challenging. One class of preparation strategies are optical methods, which have been enormously successful for atoms. Adapted versions of laser cooling, which try to optimize optical pumping into the molecular ground state, have been proposed [1], but their efficiency is limited by the absence of closed transitions in molecules. A more viable avenue seems the use of cavities for cooling, which would avoid the leakage by open transitions. For instance, efficient cavity cooling of the external degrees of freedom has been proposed in Refs. [2]. For atoms, cavity cooling was recently demonstrated [3].

We present a theoretical approach [4,5] for the simulation of the cooling of internal and external molecular degrees of freedom in a cavity. The idea is to sequentially depopulate excited rovibrational levels by vacuum-simulated Raman scattering into the mode of a high-finesse cavity. As model systems we choose the OH and the NO radicals. By using a combination of ab initio quantum chemical and experimental data we are able to determine the internal energy level structure and the transitions frequencies and strengths needed for our cooling scheme. We take into account the perturbing spontaneous and the coherent Raman processes amplified by the cavity to get a realistic model. This gives us insight in the cooling process and lets us predict the time scales needed to prepare a molecule in its ground state.

![Diagram](image.jpg)

Figure. Schematic representation of the molecular level structure. The cooling process is driven by a pump laser, and the modes of a high-finesse cavity. Due to the decay of the cavity modes the stimulated Raman process can be steered in a desired direction and dissipation is much faster than the spontaneous decay of excited states.

References
**Stark deceleration of cold lithium hydride molecules**

Centre for Cold Matter, Blackett Laboratory, Imperial College London, UK*

We will present results demonstrating the deceleration of cold lithium hydride molecules. The molecules are seeded into a pulsed supersonic expansion by ablating lithium into a carrier gas containing hydrogen. By driving the rotational transition at 444GHz, the molecules are prepared in the first rotationally excited state. They are then slowed down in a 100-stage Stark decelerator, and are finally detected by laser induced fluorescence. This work is part of a larger programme to sympathetically cool LiH using ultracold Li.

**Cavity-mediated cooling with a single mirror**

*Tim Freegarde and Peter Horak*

Just as an atom can replace one mirror in the Casimir effect, so cavity-mediated cooling appears possible through the retarded interaction of an illuminated particle with - or optical binding to- its own reflection. External cavity/plasmon resonances within the mirror offer to enhance this process, which may then be extended across a broad array. We describe our ongoing theoretical treatment of single mirror cooling, as well as planned experiments that are currently being assembled.
Matter Wave Interference and Matter Wave Interferometry with Interactions: Quantum Carpets and Matter Wave Spin Echo

Mattias Gustavsson, Elmar Haller, Manfred J. Mark, Johann G. Danzl, Russell Hart, Andrew Daley, Hanns-Christoph Nägerl

We observe matter wave interference which is driven by interactions. For a Bose-Einstein condensate the wave function coherently evolves into a macroscopic “quantum carpet” as a result of Bloch oscillations. Coherence is demonstrated in a matter wave spin echo experiment by reversing the evolution upon switching the strength of the interaction to zero and applying a harmonic potential. As an application, we perform matter wave interferometry in the presence of interactions: Persistent Bloch oscillations are observed for an interacting trapped condensate when the effect of interactions is balanced by the harmonic trapping potential.

Fermi gases and FFLO state in optical lattices and exact dynamics of RF-spectroscopy


We consider density imbalanced Fermi gases in 1, 2, and 3 dimensional optical lattices. We find the parameter window for FFLO state versus phase separation to be considerably larger than in the free space case, due to the flatness and nesting of the majority and minority component Fermi surfaces in the lattice [2]. The VanHove singularities leave striking signatures to the phase diagrams and the FFLO state is clearly reflected in noise correlations especially in 1 D [2], making observation of the state feasible. In 1 D, we present a comparison between mean field and exact Matrix Product State results. We also present Matrix Product State method simulations of coherent RF-spectroscopy for paired 1 D systems [3]. This allows obtaining exact results on the spectra without mean field and linear response approximations. We compare our results to sum rule and linear response based results and find suppression of the pairing signal by non-linear effects.

Formation of ultracold LiCs molecules

R. Wester, J. Deiglmayr, A. Grochola, C. Glück, K. Mörtl Bauer, J. Lange, S. Kraft, M. Weidemüller

We present the active photoassociation of ultracold LiCs molecules, stabilized by radiative decay, and find photoassociation resonances in the B1Π potential correlated to the 2S1/2–6P3/2 asymptote. Using multiphoton ionization spectroscopy with a high-resolution time-of-flight mass spectrometer[1], we identify LiCs vibrational levels in the X1Σ ground electronic state. Active photoassociation in an overlapped Cs DarkSPOT/Li MOT is found to yield a strongly increased production rate compared to photoassociation by the trapping light of a two-species MOT [2]. The perspectives for the production of LiCs molecules in the absolute ground state are evaluated and future experiments with an ultracold gas of polar LiCs molecules are outlined.


Disorder-Induced Order in Ultracold Fermi Gases

Armand Niederberger, Krzysztof Sacha, Jan Wehr, Maciej Lewenstein

We consider a superfluid mixture of fermionic atoms in two different internal states with attractive interaction together with a big molecular BEC made of the same atoms. In absence of photoassociative coupling, the relative phase between the pairing (gap) function and the BEC wavefunction is arbitrary. Our studies show that by introducing a weak spatially random coupling of mean zero, the relative phase becomes locked at values around /2. Hence, controllability and order in the relative phase are reached by disordered couplings illustrating the surprising effect of disorder-induced order.
Molecular collision studies with Stark-decelerated beams

Gerard Meijer. Fritz-Haber-Institut der Max-Planck-Gesellschaft

Molecular scattering behaviour has generally proven difficult to study at low collision energies. We formed a molecular beam of OH radicals with a narrow velocity distribution and a tunable velocity by passing the beam through a Stark decelerator [1].

The transition probabilities for inelastic scattering of the OH radicals with Xe atoms were measured as a function of the collision energy in the range of 50 to 400 wavenumbers. The behaviour of the cross-sections for inelastic scattering near the energetic thresholds was accurately measured, and excellent agreement was obtained with cross-sections derived from coupled-channel calculations on ab initio computed potential energy surfaces [2].

For collision studies at lower energies, the decelerated beams of molecules can be loaded into a variety of traps. In these traps, electric fields are used to keep the molecules confined in a region of space where they can be studied in complete isolation from the (hot) environment. Typically, 10^5 state-selected molecules can be trapped for times up to several seconds at a density of 107 mol/cm^3 and at a temperature of several tens of mK [3].

The long interaction time afforded by the trap has been exploited to measure the infrared radiative lifetime of vibrationally excited OH radicals, for instance, as well as to study the far-infrared optical pumping of these polar molecules due to blackbody radiation [4].

As an alternative to these traps, we have demonstrated an electrostatic storage ring for neutral molecules. In its simplest form, a storage ring is a trap in which the molecules – rather than having a minimum potential energy at a single location in space – have a minimum potential energy on a circle. To fully exploit the possibilities offered by a ring structure, it is imperative that the molecules remain in a bunch as they revolve around the ring. This ensures a high density of stored molecules, moreover, this makes it possible to inject multiple – either co-linear or counter-propagating – packets into the ring without affecting the packet(s) already stored. We have recently demonstrated a prototype molecular synchrotron, which will be used as a low-energy collider for neutral molecules in the future [5].

**Repulsive shield between polar molecules**

*H.P. Büchler, A.V. Gorshkov, P. Zoller, M. Lukin*

We present the realization of a repulsive shield between polar molecules which allows for the suppression of inelastic collisions and increases the life time of cold polar molecules. The main idea is to cancel the leading dipole-dipole interaction with a suitable combination of static electric field and microwave fields. The remaining interaction is repulsive with a van der Waals behavior. We analyze in detail the elastic and the inelastic scattering cross section, and outline a method towards efficient evaporative cooling of polar molecules. Furthermore, we show that this setup is suitable for the realization of three-dimensional crystalline structures.

**Quantum Gas of Deeply Bound Ground State Molecules**

*Johann G. Danzl, Elmar Haller, Mattias Gustavsson, Manfred J. Mark, Russell Hart, Nadia Bouloufa, Olivier Dulieu, Helmut Ritsch, Hanns-Christoph Nägerl*

We create an ultracold dense quantum gas of deeply bound molecules in the v=73 vibrational level of the singlet potential bound by more than 1000 wavenumbers by coherent optical two-photon STIRAP transfer of molecules produced on a Feshbach resonance from a Bose-Einstein condensate of cesium atoms. The transfer efficiency exceeds 60%. We discuss the progress for the implementation of the next step in which we aim to transfer the molecules into the ro-vibrational ground state. Our results show that the creation of a Bose-Einstein condensate of ro-vibrational ground state molecules is within reach.
Heteronuclear Feshbach resonances in a mixture of ultracold $^{87}$Rb and $^{133}$Cs

A.D. Lange $^1$, K. Pilch $^1$, A. Prantner $^1$, F. Ferlaino $^1$, G. Kerner $^2$, H.-C. Nägerl $^1$, R. Grimm $^{1,2}$

$^1$Institut für Experimentalphysik, Universität Innsbruck, Innsbruck, Austria
$^2$Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Austria

We present the first observation of heteronuclear Feshbach resonances in a bosonic mixture of ultracold $^{133}$Cs and $^{87}$Rb. We give an overview of our experimental setup and the procedure of all-optical sample preparation. One of the key ingredients is the use of simultaneous degenerate Raman sideband cooling on both species. We perform Feshbach spectroscopy on a mixture of $\sim 10^6$ atoms, optically trapped at a temperature of a few $\mu$K, by recording trap loss. We find a rich structure of interspecies Feshbach resonances within a magnetic field ranging from 0G to 300G. A consistent assignment of the observed Feshbach resonances will allow us to quantify the interspecies collisional properties. We discuss potential pathways towards obtaining a double-degenerate bosonic quantum gas and towards the production of ground state RbCs molecules.
New analysis of REMPI spectra of ultracold rubidium molecules

A. Fioretti¹, A. Gerdes², O. Dulieu³, and C. Gabbanini¹

¹. Istituto per i Processi Chimico-Fisici, IPCF-CNR, via Moruzzi 1, 56124 Pisa, Italy
². Physikalisches Institut., Universität Freiburg, Hermann Herder Str.3, D-79104 Freiburg im Br., Germany
³. Laboratoire Aimé Cotton, CNRS, Bât.505, Univ Paris-Sud, 91405 Orsay cedex, France

Experimental spectra of REMPI detection of ultracold rubidium dimers obtained by our group in Pisa and by the group at the University of Connecticut in Storrs [Y. Huang, PhD thesis, 2006] are reinvestigated using the Mapped Fourier Grid Method and newly computed potential surfaces including spin-orbit interaction. Several features of these spectra for which the excitation mechanism has not been completely clarified are studied, in particular states that show a singlet-triplet mixing. Interesting possibilities could be foreseen for both the production and the detection of ultracold molecules in the ground singlet state.

On the quantum optical heating in sonoluminescence experiments

Andreas Kurcz and Almut Beige

Sonoluminescence is the intriguing phenomenon of strong light flashes from tiny bubbles in a liquid. These bubbles are driven by an ultrasonic wave and need to be filled with noble gas atoms. The spectrum of the emitted light corresponds to very high temperatures. Although studied extensively, the origin of the observed sudden temperature increase is still highly controversial. We show that it can be caused by a very weak but highly inhomogeneous electric field as it occurs during rapid bubble deformations. The field couples the quantised motion of the atoms to their electronic states, thereby resulting in very high heating rates and in the excitation of atomic states. Our model clarifies the role of the noble gas atoms and explains the presence of emission lines in the optical regime, independent of the temperature of the bubble.
Towards quantum simulators with \textsuperscript{40}K-\textsuperscript{6}Li Fermi mixtures

A. Ridinger, T. Salez, K. Magalhães, D. Wilkowski, F. Chevy, and C. Salomon

In our new experiment, we aim at studying mixtures of \textsuperscript{40}K and \textsuperscript{6}Li in bulk and in optical lattices. In order to obtain new insights into condensed matter physics phenomena, we will simulate the Fermi-Hubbard Hamiltonian, Heisenberg Hamiltonian and Quantum Hall Hamiltonian. We will investigate the relationship between high Tc superconductivity and superfluidity in Fermi mixtures with imbalanced Fermi surfaces, in particular in 2D systems. We will explore the creation of Wigner crystals of heteronuclear molecules in the limit of large scattering lengths. Setting the Fermi gas in rotation is the equivalent of applying a magnetic field in condensed matter systems and should give access to Landau level physics and fractional quantum Hall effect. We present the current design of our experiment. We have achieved trapping of \textsuperscript{39}K atoms in a magneto-optical trap, and we are now working on the double species MOT and the \textsuperscript{6}Li Zeeman slower. The atoms will then be magnetically transported towards the science chamber where we intend to evaporate the mixture to quantum degeneracy and to set up the various optical.
5_

Cavity-assisted laser cooling of linearly polarisable particles --- prospects of "molecooling"

Andras Vukics, Janos Asboth, Benjamin L. Lev, Peter Domokos, Jun Ye, and Helmut Ritsch

Cooling of molecules via free-space dissipative scattering of photons is thought not to be practicable due to the inherently large number of Raman loss channels available to molecules and the prohibitive expense of building multiple-repumping laser systems. The use of a lossy mode of an optical cavity as an alternative decay channel has been suggested as a potential method to mitigate Raman loss, thereby enabling the laser cooling of molecules to ultracold temperatures.

First in a short review of recent work on the subject we discuss the possibility of cavity-assisted laser cooling of particles without closed transitions, identify conditions necessary to achieve efficient cooling, and suggest solutions given experimental constraints.

Specifically, it is shown that cooperativities much greater than unity are required for cooling without loss, and that this could be achieved via the superradiant scattering associated with the intracavity self-organisation of the molecules. As a specific example we discuss experimental possibilities for the polar hydroxyl radical (OH).

6_

Ultracold Molecules in Combined Electric and Magnetic Fields: a New Type of Conical Intersection

Alisdair O. G. Wallis and Jeremy M. Hutson

Electronic potential energy surfaces of the same symmetry will avoided cross in one dimension, and form a double cone that intersects at a point in two dimensions (a conical intersection).

Externally applied electromagnetic fields can be used to split and shift the rovibrational states of an ultracold molecule. Using such external fields, a situation can be created in which two states of opposite parity cross as a function of magnetic field, and then avoided cross in the presence of an additional electric field. This forms a conical intersection in the spatial dimensions of the electromagnetic fields.
7

Semiclassical theory of coherent atom cooling with a single mirror

André Xuereb, Peter Horak, Tim Freegarde

We investigate theoretically a novel optical technique to cool atomic or molecular species without a closed transition: a particle in front of a mirror illuminated by an off-resonant light beam. The interaction between the particle, the pump and the time-delayed reflected pump results in a net loss of energy from the particle to the field and therefore cooling. Cooling rates depending on particle position and coupling parameters are obtained by an analytical perturbative approach. Finally, we present a semiclassical computational model incorporating momentum diffusion, which will eventually allow us to predict steady-state temperatures.

8

Energy levels of RbCs and KRb in the presence of external fields.

B. Rivington, J. Aldegunde, P. Zuchowski and J. M. Hutson

The study of cold molecules has unveiled a wide range of novel possibilities regarding reaction dynamics and quantum control. All the techniques devised to prepare such molecules (Feshbach resonances, photoassociation, Stark deceleration, sympathetic cooling) involve the use of magnetic and electric fields. The experimental work will therefore be largely facilitated by a priori knowledge of how the energy levels of the molecules behave in the presence of external fields. The results included in this poster illustrate this behaviour by means of examples corresponding to the RbCs and KRb diatomic molecules, two of the most promising systems currently under research.
9_

Production of a continuous guided beam of slow and internally cold molecules from a cryosource


We have developed a new cold molecule source delivering a continuous beam of slow and internally cold polar molecules. In the source, room-temperature molecules are injected into a cryogenic helium buffer gas where they are cooled in all degrees of freedom. A fraction is extracted by an electric quadrupole guide and transported to an ultrahigh-vacuum region for detection. By selectively depleting rotational states with a UV laser copropagating with the guided molecules, we are able to measure their internal state distribution.

10_

Dipolar Bosons in a 2D optical lattice

C. Trefzger, C. Menotti, and M. Lewenstein

We investigate the physics of dipolar bosons in a two-dimensional optical lattice. We consider the properties of the system beyond its ground state, finding that it is characterized by a multitude of almost degenerate metastable states, often competing with the ground state. This makes dipolar bosons in a lattice similar to a disordered system and opens possibilities of using them as quantum memories.

We focus our attention on the problem of passing, in a controlled way, from one metastable configuration to another. We find that it is necessary to break the symmetry of the initial state by going into the superfluid region in order to reach the desired final state.
11_

Broken symmetry ground and excited states of small rotating bosonic and fermionic systems *

D. Dagnino, A. Riera, K. Osterloh, J. Taron, N. Barberan and M. Lewenstein *

We analyze different equilibrium states of small systems realized as the rotation frequency of the confining potential trap changes. Order structures are observed: in some cases hidden interference patterns exhibit themselves only in the pair correlation function or in other cases, broken-symmetry structures modulate the density. In the case of fermions with dipole-dipole interaction, we find novel quasi-hole states which are not properly described within the composite fermion picture.

For bosons, at relatively low frequencies, when the degree of condensation is high, we approximate the state with an order parameter introduced in a rigorous way.

12-

Self-organization of a Bose-Einstein condensate in an optical cavity

D. Nagy, G. Szirmai, P. Domokos

The spatial self-organization of a Bose-Einstein condensate (BEC) in a high-finesse linear optical cavity is discussed. The condensate atoms are laser-driven from the side and scatter photons into the cavity. Above a critical pump intensity the homogeneous condensate evolves into a stable pattern bound by the cavity field. The transition point is determined analytically from a mean-field theory. We calculate the lowest lying Bogoliubov excitations of the coupled BEC-cavity system and the quantum depletion due to the atom-field coupling.
13_

**Cold collisions in a $^{87}\text{Rb} - ^{133}\text{Cs}$ mixture**

*D. J. McCarron, M. L. Harris, P. Tierney and S. L. Cornish*

Quantum degenerate mixtures offer a route to the formation of ultracold heteronuclear molecules via photoassociation or a Feshbach resonance which in turn facilitate the creation of dipolar quantum gases. We present an apparatus designed to study ultracold mixtures of $^{133}\text{Cs}$ and $^{87}\text{Rb}$. The mixture is prepared using a two-species pyramid MOT as a cold atom source for a UHV ‘science’ MOT. Studies of losses in the two-species MOT are presented. After the initial MOT phase, atoms are transferred to a purely magnetic trap. We describe ongoing experiments to search for interspecies Feshbach resonances and to investigate sympathetic cooling of $^{133}\text{Cs}$.

14_

**Cold polar molecules and molecular spectroscopy**

*E. Tiemann, H. Knöckel, A. Gerdes, A. Stein, A. Pashov*

The application of cold atomic and/or molecular ensembles asks for good knowledge of molecular structure combining theoretical results like ab initio calculations with spectroscopic studies. We will report on the present status of spectroscopy in the group of heteronuclear alkalis and about possibilities in the alkaline earth group. The modeling with appropriate molecular potential representations is of special interest to allow for reliable predictions of cold collisions and the behavior of ultracold ensembles of mixed species in external fields. The precise evaluation of the excited levels obtained form the spectroscopy is also important to open ways for manipulating cold molecular ensembles.
15_

Exploring ultracold Fermi-Fermi mixtures: part I - overview

E. Wille, F.M. Spiegelhalder, G. Kerner, D. Naik, A. Trenkwalder, G. Hendl, F. Schreck, R. Grimm

We are exploring Fermi-Fermi mixtures of lithium, potassium and strontium. This poster motivates our research and gives a general overview of the experimental apparatus.

16_

Ultracold Cesium molecules and Cs-Rb mixtures

F. Ferlaino, S. Knoop, M. Mark, M. Berninger, H. Schöbel, H. C. Nägerl, and R. Grimm

We produce weakly bound optical trapped Cs2 molecules by Feshbach association. We explore the collisional rate between Cs atoms and s-wave Cs2 molecules as a function of magnetic field. We find a pronounced resonant enhancement of the loss rate for a particular value of the scattering length induced by a trimer state near the molecular scattering continuum, which has important consequences within the Efimov physics. We also study the collisional properties of pure molecular samples. The s-wave molecules show an unexpected dependence of their collisional rate on the s-wave atomic scattering length with a collisional suppression at a=300 a0. Finally, we discuss our recent result on the Cs-Rb Feshbach spectroscopy.
**17_**

**BEC-BCS Crossover in ultracold Fermi gas: a new experimental setup**

G. Duffy, S. Nascimbene, N. Navon, L. Tarruell, F. Chevy, C. Salomon

We present the building of a next generation experimental setup, which uses bosonic Li7 to sympathetically cool fermionic Li6. It will be used to study strongly interacting Fermi gases through the BEC/BCS crossover, using the broad Feshbach resonance. We have already been able to achieve magneto-optical trapping of both isotopes. We magnetically transport the gas to a Ioffe trap where we perform Doppler cooling and then an evaporative cooling in order to load the atoms in a deep optical trap. We will present the latest performance of our setup, which already includes a ten-fold improvement of atom number comparing to the previous experiment. This setup will be upgraded with an optical lattice, in order to experimentally study model hamiltonians of condensed matter physics.

**18_**

**Exploring ultracold Fermi-Fermi mixtures: part II - technology**

G. Hendl, A. Trenkwalder, E. Wille, F.M. Spiegelhalder, G. Kerner, D. Naik, F. Schreck, R. Grimm

We are exploring Fermi-Fermi mixtures of lithium, potassium and strontium. This poster concentrates on three technological details: the multi-species atomic beam source, the magnetic field coils and the resonator optical dipole trap.
19_

Cavity cooling of molecules to the ground state

G. Morigi, P. Pinkse, M. Kowalewski, and R. de Vivie-Riedle.

We predict that it is possible to cool rotational, vibrational and translational degrees of freedom of molecules by coupling a molecular dipole transition to an optical cavity. The dynamics is numerically simulated for a realistic set of experimental parameters using OH molecules. The results show that the translational motion is cooled to few $\mu$K and the internal state is prepared in one of the two ground states of the two decoupled rotational ladders in few seconds. Shorter cooling times are expected for molecules with larger polarizability.

20_

Floating crystals and lattices of polar molecules

G. Pupillo, A. Griessner, A. Micheli, M. Ortner, D.-W. Wang, P. Zoller

We discuss the possibility to realize 2D self-assembled crystals using polar molecules interacting via electric-field-induced dipole-dipole potentials. These crystals are obtained via a superfluid-crystal quantum phase transition and can be utilized as floating lattice structures to trap extra-particles, e.g. cold atoms and polar molecules. Within an experimentally accessible parameter regime extended Hubbard models with tunable long-range phonon-mediated interactions describe the effective dynamics of dressed particles.
21_

Towards quantum gases of polar KRb molecules

G. Roati, M. Zaccanti, G. D’Errico, M. Fattori, M. Inguscio, A. Simoni, G. Modugno

Quantum degenerate atomic mixtures with tunable interactions are promising for the production of quantum gases of polar molecules. In this context, K-Rb mixtures are appealing, since both fermion-boson and boson-boson pairs are available and the main isotopic combinations present several Feshbach resonances. We have characterized the scattering properties of different K-Rb systems by means of Feshbach spectroscopy. This has allowed us to construct an accurate near-threshold model for scattering and bound-state calculations able to determine precisely near threshold parameters for all K-Rb pairs. We are using the model to develop schemes for efficient transfer of Feshbach molecules to their ground state.

22_

Geometric resonance cooling of polarizable particles in an optical waveguide

G. Szirmai, P. Domokos

In the radiation field of an optical waveguide, the Rayleigh scattering of photons is shown to result in a strongly velocity-dependent force on atoms. The pump field, which is injected in the fundamental branch of the waveguide, is favorably scattered by a moving atom into one of the transversely excited branches of propagating modes. All fields involved are far detuned from any resonances of the atom. For a simple polarizable particle, a linear friction force coefficient comparable to that of cavity cooling can be achieved.
23_

**Optimal spin squeezing inequalities for detecting entanglement with collective measurements**

*G. Tóth, C. Knapp, O. Gühne, and H.J. Briegel*

We discuss entanglement detection in a system of many spin-1/2 particles in which the particles cannot be individually addressed. In particular, we describe the complete set of generalized spin squeezing inequalities that detect entanglement with the first and second moments of the collective angular momentum components. These finding are relevant to recent experiments for creating highly entangled states with cold atoms.

24_

**Phase diagram of low dimensional dipolar gases with transverse confinement: linear, zig-zag and multiple chains**

*G.E. Astrakharchik and G. Morigi*

We study the ground state properties of ultracold dipolar gases, starting from a one-dimensional geometry in a tightly anisotropic trap. By ramping down the transverse confinement along one direction, the gas reaches various planar distributions of dipoles. At large linear densities (when the dipolar chain exhibits quasi long-range order), one can identify critical values of the transverse frequency at which the configuration starts exhibiting novel transverse spatial correlations. These critical values can be identified by means of a classical theory, and are in full agreement with zero-temperature quantum Monte Carlo simulations.
25_

Destroying superfluidity rotating a fermi gas at unitarity

I. Bausmerth, A. Recati, S. Stringari

We study the effect of the rotation on a harmonically trapped Fermi gas at zero temperature under the assumption that vortices are not formed. We show that at unitarity the rotation produces a phase separation between a nonrotating superfluid (S) core and a rigidly rotating normal (N) gas. The interface between the two phases is characterized by a density discontinuity $n_N/n_S = 0.85$, independent of the angular velocity. The depletion of the superfluid and the angular momentum of the rotating configuration are calculated as a function of the angular velocity. The conditions of stability are also discussed and the critical angular velocity for the onset of a spontaneous quadropole deformation of the interface is evaluated.

26_

Effects of rotation on a Fermi Gas at Unitarity

Ingrid Bausmerth, Alessio Recati, Sandro Stringari

We study the effect of the rotation on a harmonically trapped unitarity Fermi gas at zero temperature under the assumption that vortices are not formed. In the case $P=0$ the rotation produces a phase separation between a nonrotating superfluid (S) core and a rigidly rotating normal (N) gas. The interface between the two phases is characterized by a density discontinuity $n_N/n_S = 0.85$, independent of the angular velocity. We evaluate the depletion of the superfluid and the angular momentum of the rotating configuration as a function of the angular velocity. In the case of a finite polarization $P \neq 0$ however the striking difference is the dependence of the density discontinuity $n_N/n_S$ on the angular velocity.
27_

**Collective Excitations and Instability of an Optical Lattice due to Unbalanced Pumping**

*J. Asboth, H. Ritsch, P. Domokos*

Traveling density wavelike collective oscillations can arise in an asymmetrically pumped optical lattice, and can destabilize the structure even in the overdamped limit. The long-range interaction giving rise to collective motion stems from the back-action of the atoms on the field creating the lattice. We derive the force on particles including the back-action on the light, and analyze its relation to the standard perturbative approach giving the "dipole force" and "radiation pressure". The self-consistent lattice constant decreases as the pump asymmetry is increased. The lattice vibration eigenmodes reveal that the instability is enhanced resonantly at certain settings of the asymmetry.

28_

**Investigation of cold atoms near nano-structured surfaces**

*James Bateman, Andre Xuereb, Hamid Ohadi, Richard Murray, Tim Freegarde*

We present the design of apparatus to be used to investigate the interaction of cold atoms with a nano-structured surface. The approach described includes techniques for: accumulation of a sample of cold atoms; transportation of these atoms to the sample without introducing significant heating or centre of mass motion; confinement of the atoms at a controlled distance from the surface whilst also ensuring they are transversely confined; illumination of the sample to create dipole force traps; and observation of the effect of individual sites on the surface, and of collective effects of the array.
29_

Spectroscopy of ultracold LiCs molecules

J. Deiglmayr, A. Grochola, C. Glück, K. Mörtlbauer, J. Lange, O. Dulieu, R. Wester, and M. Weidemüller

We recently achieved the photoassociation of ultracold LiCs molecules in a double species magneto optical trap [1]. The molecules were ionized by one-color two-photon ionization and detected with a high-resolution time-of-flight mass spectrometer [2]. Implementing a forced dark SPOT for Cesium greatly enhanced photoassociation rates. Here we present photoassociation spectra and identify rovibrational levels in the B¹ state. Ionization spectra of the produced ground state molecules are compared with ab-initio predictions and vibrational levels in the X¹ state are identified. The perspectives for the production of LiCs molecules in the absolute ground state and the alignment of these molecules in moderate external fields are evaluated.


30_

Instabilities of cold spinless fermions in a pumped optical resonator

Jonas Larson, Giovanna Morigi, and Maciej Lewenstein

We study systems of fully polarized ultracold fermions inside a pumped cavity. The effect of the matter-field non-linear interaction leads to several kind of instabilities, both in field intensity, and in number of atoms. The quantum nature of the atomic motion is considered. Hence, the field bistability goes beyond regular semi-classical approaches, and we study the interplay between "semi-classical" and “quantum” instabilities. We analyze the case of non-fixed atom number in the limit of steady state, and find that the number of atoms that minimizes the energy may change considerably for small parameter changes.
31_

**Microscopic description of atomic Bose-Einstein condensates in the large-gas-paremeter region**

*J. Mur-Petit, M. Guilleumas, and A. Polls*

In this talk we compare the results of the Gross-Pitaevskii and modified Gross-Pitaevskii equations with ab initio variational Monte Carlo calculations for Bose-Einstein condensates of atoms in axially symmetric traps. We examine both the ground state and excited states having a vortex line along the z axis at high values of teh gas paremeter and demonstrate an excellent agreement between the modified Gross-Pitaevskii and ab initio Monte Carlo methods, both for the ground and vortex states.

32_

**Superfluid boson currents and long range interactions in 1D optical lattices**

*J. Schachenmayer, A. J. Daley, G. Pupillo, and P. Zoller*

The decay of superfluid currents for Bosons moving in an optical lattice potential has attracted a lot of recent attention. In particular, experiments have shown that the decay of currents in 1D systems differs markedly from the mean-field prediction. We investigate this system here, computing the time evolution within the Bose-Hubbard model using the infinite Time Evolving Block Decimation Algorithm, and find good agreement with the experimental results. We also report on progress in extending the algorithm to allow simulation of long-range interactions, especially for the case of polar molecules in an optical lattice.
33_

Helium 2 \(^3\)S – 2 \(^1\)S metrology at 1557 nm

K.A.H. van Leeuwen and W. Vassen

An experiment is proposed to excite the ‘forbidden’ 1s2s \(^3\)S\(_1\) - 1s2s \(^1\)S\(_0\) magnetic dipole (M1) transition at 1557 nm. Doppler-free excitation of 2% of trapped and cooled atoms may be realised in a one-dimensional optical lattice geometry, using a narrowband 2 W laser both for trapping and spectroscopy. The very small (8 Hz) natural linewidth of the transition presents an opportunity for accurate tests of atomic structure calculations of the helium atom. A measurement of the \(^3\)He - \(^4\)He isotope shift allows for accurate determination of the difference in nuclear charge radius of both isotopes.

34_

Frequency-comb-phase locked laser sources for multiresonant spectroscopy of metastable atomic Helium around 1083 nm

L. Consolino \(^1\), G. Giusfredi \(^1,2\), P. De Natale \(^1,2\), M. Inguscio \(^1\) and P. Cancio \(^1,2\)

1. LENS and Dipartimento di Fisica, Università di Firenze
2. INOA-CNR

We have recently improved our experimental set-up in order to realize multiresonant spectroscopy of He transitions at 1083 nm. We directly phase-lock different 1083 nm lasers to the nearest teeth of an Optical Frequency Comb (OFC), then performing simultaneous spectroscopic recordings of different He transitions by scanning the OFC repetition rate. In this way, optical frequencies and microwave frequency differences are measured. The frequency precision is improved and time-dipendent-systematic effects are cancelled at least in the frequency differences. This set-up can also be used for other spectroscopy schemes as EIT, dark resonances and Raman, and to measure small frequency shifts.
35_

**Quantum Dynamics of OH + CH₄ → H₂O + CH₃**

*Liesbeth M. C. Janssen, Simon T. Banks, David C. Clary, Gerrit C. Groenenboom, and Ad van der Avoird*

A 2D quantum scattering model has been used to study the reaction OH + CH₄ → H₂O + CH₃. The method treats explicitly the bonds being broken and formed, while the remaining degrees of freedom are accounted for by an adiabatic approach. The potential was obtained by fitting a double Morse function to a set of *ab initio* points calculated at the CCSD(T)//MP2/cc-pVTZ level of theory. The results indicate that the reaction is significantly enhanced by excitation of the C-H stretch. The calculated rate constants compare very favorably with experiment, although the Arrhenius curvature is not completely reproduced.

36_

**Crossed beam scattering experiments using Stark decelerated beams**

*Ludwig Scharfenberg, Joop J. Gilijamse, Steven Hoekstra, Henrik Haak, Sebastiaan Y.T. van de Meerakker, Gerard Meijer*

The main goal of our experiment is to study collisions between quantum state selected polar molecules in the gas phase. Two long Stark decelerators that cross under a fixed angle of 90° will produce the state selected packages of molecules; moreover, they will give us complete control over the velocity and velocity distribution of the molecules. We should thus be able to investigate how the scattering cross sections for inelastic processes depend on the (continuously variable) collision energy.
37_

**Vortex rings in toroidal Bose-Einstein condensates**

*M. Abad, M. Guilleumas, M. Pi and R. Mayol*

We study vortex ring solutions of the Gross-Pitaevskii equation for Bose-Einstein condensates confined in toroidal traps. Analogously to the Feynmann-Onsager ansatz for a single vortex line, we assume a condensate wave function that describes a quantized vortex ring. This leads to a modified Gross-Pitaevskii equation that incorporates vortex ring solutions with the circulation quantized on the rz-plane. By solving numerically this equation we have obtained the density profiles and the vortex core structure. We have also studied the nucleation energy of a vortex ring, and analysed the dependence on the on the position and radius of the ring. Finally, a qualitative description of the vortex ring dynamics is presented.

38_

**Cold Ytterbium atoms in High-finesse optical cavities: Cavity Cooling and Collective Interactions**

*M. Cristiani, T. Valenzuela, H. Gothe, J. Eschner*

The quantum behavior of cold atoms interacting with photons confined in high-finesse cavities has been a subject of rising interest during the last decade. In particular new schemes for laser cooling based on cavity feedback have been extensively studied both theoretically and experimentally. Here we present the status of the experimental setup we are developing at ICFO. This apparatus will be suitable for studying collective excitation of a cold atomic cloud interacting with the mode of a resonator, with the perspective of using this system for investigating new cooling mechanisms based on atom-cavity interaction. We recently observed cooling and confinement of $^{174}$Yb atoms in a Magneto-Optical Trap operating on the $^{1}S_0\rightarrow^{1}P_1$ transition ($\lambda=399$nm, $\Gamma=2\pi\cdot28$ MHz). At the moment we are setting up a laser source tuned on the $^{1}S_0\rightarrow^{3}P_1$ inter-combination transition ($\lambda=556$nm, $\Gamma=2\pi\cdot182$ kHz). In the next future we planned to use this transition to improve the cooling process. At the same time a high-finesse cavity tuned at 556nm is being designed. Our medium term goal is to include this setup in the vacuum system during the next mounts.
Molecular Vibrational Quantum Computing with non-Resonant Raman Quantum Gases

M. Kowalewski, C. Gollub and R. de Vivie-Riedle.
Department Chemie und Biochemie, Ludwig-Maximilians-Universität

The concept of molecular vibrational quantum computing is based on qubits encoded in eigenstates of vibrational normal modes and ultrashort, specially-shaped pulses operating as quantum logic gates (1). Our new approach for implementation of quantum gate operations is based on a nonresonant stimulated Raman process. One of the advantages of this idea is the higher flexibility in the choice of laser wavelengths in combination with established shaping techniques in the visible frequency domain. Additionally, chirped pulses might be used as quantum gates and within this approach the normal modes which are not addressable by an IR process become accessible. The quantum gates can be optimized by a modified Krotov-OCT-scheme including restrictions on the laser fields in the frequency domain to assure simple pulse spectra (2). Stimulated Raman quantum gates are presented for a 2D-qubit system of the molecule butylamine, which is described fully quantum chemically by calculation of 2D potential energy surface and the polarizability tensor along two selected normal modes.


RF-Spectroscopy of 1D fermi gases in an optical lattice

Mikko Leskinen, M. Reza Bakhtiari and Paivi Torma

We consider RF-spectroscopy of ultracold Fermi gases by exact simulations of the many-body state and the coherent dynamics in one dimension. Deviations from the linear response sum rule result are found to suppress the apiring contribution to the RF line shifts. We compare our results with the mean-field description by Bogoliubov-de Gennes formalism.
41_

**Predicting spinor condensate dynamics from simple principles**

*M. Moreno-Cardoner, J. Mur-Petit, M. Guilleumas, A. Polls, A. Sanpera and M. Lewenstein*

The spin dynamics of quasi-1d $F=1$ condensate at zero and finite temperatures have been studied for arbitrary initial spin configurations. The rich dynamical evolution exhibited by these nonlinear systems is explained by surprisingly simple principles: minimization of energy at $T=0$ and maximization of entropy at high temperature. Our analytical results for the homogeneous case are corroborated by numerical simulations for confined condensates in a wide variety of initial conditions. These predictions compare qualitatively well with recent experimental observations and can serve as a guidance for ongoing experiments.

42_

**Optical experiments with cold guided molecules**

*M. Motsch, M. Schenk, L.D. van Buuren, M. Zeppenfeld, P.W.H. Pinkse and G. Rempe*

We present measurements of the internal state distribution of electrostatically guided formaldehyde molecules. By addressing individual rotational levels with a tunable UV laser, the molecules are pumped to a predissociating state, causing a loss in the guided flux. To further cool molecules to the ultracold regime, cavity cooling is considered. As a first step in this direction we investigate Rayleigh scattering into an optical cavity by a room-temperature molecular sample, which allows deduction of experimental constraints for such experiments with guided molecules.
43_

**Optimised Particle Transport via a Harmonic Potential**

*Michael Murphy, Tommaso Calarco*

Quantum state transfer through a spin chain is an implementation of quantum channels for use in quantum information processing. Recently, a method was proposed for robust adiabatic quantum population transfer through a quantum spin chain by application of a slowly moving parabolic magnetic potential with a constant velocity. In our work, optimal control theory is applied to find optimised control pulses for the parabolic potential (both for the velocity and the relative coupling strength of nearest-neighbour spins), and the fidelity of the state transfer over shorter time scales is considered.

44_

**Quantum non-demolition measurement of Fermi correlations**

*M. Rodriguez, O. Romero-Isart, K. Eckert, T. Roscilde, M. Lewenstein, E. Polzik and A. Sanpera*

We show how to detect superfluid phases of ultracold fermionic atoms in a quantum non-demolition and spatially resolved way by probing them with polarized laser beams. Polarization degrees of freedom of light couple to spatially resolved components of the atomic spin. In this way quantum fluctuations of matter are faithfully mapped on those of light; the latter can then be efficiently measured using homodyne detection.
45_

**New results on low v cold molecule formation**

*Matthieu Viteau, Amodsen Chotia, Maria Allegrini, Nadia Bouloufa, Daniel Comparat, Olivier Dulieu and Pierre Pillet*

One of the most exciting current challenges of the ultracold molecule researches is to produce in an efficient way ultracold molecules in their rotational and vibrational ground state. To achieve this goal, different photoassociation and excitation schemes were explored in our laboratory to create or transfer cold molecules of Cesium to the lowest ro-vibrational level of the fundamental state $X_{g^+}^{1g}$. They will be presented and discussed in this poster.

46_

**Resonator modes beyond the paraxial approximation**

*M. Zeppenfeld, M. Koch, B. Hagemann, M. Motsch, P.W.H. Pinkse, G. Rempe*

A new set of vector solutions to Maxwell's equations based on solutions to the wave equation in spheroidal coordinates allows laser beams to be described beyond the paraxial approximation. Using these solutions allows us to calculate the first-order corrections in the short wavelength limit to eigenmodes and eigenfrequencies in a Fabry Perot resonator. Experimentally relevant effects are predicted and observed for high-finesse cavities. Modes which are degenerate according to the paraxial approximation are split according to their total angular momentum. This includes a splitting due to coupling between orbital angular momentum and spin angular momentum.
47

**Cavity QED and cavity mediated cooling using ion coulomb**

*Marler, M. Albert, P.F. Herskind, A. Dantan, M.B. Langkilde-Lauesen, M. Drewsen*

Clouds of cold ions (coulombs crystals) represent an interesting alternative system to a single atom/ion for studying CQED effects. Ensembles of ions can be easily trapped and cooled in sufficient number to potentially access the strong collective coupling regime without using extremely high finesse cavities. We will present recent experimental results which indicate that the number of 40Ca+ ions inside the cavity mode of our experimental setup is in principle high enough to achieve strong collective coupling. Near future CQED experiments as well as investigations on how coupling to the cavity mode can lead to further cooling of the ion cloud will be discussed.

48

**Dynamical evolution of trapped rotating BEC's**

*Núria Barberan et al*

We analyze within exact diagonalization formalism the process of nucleation of the first vortex at the center of a bosonic system as the rotation frequency increases. During this process the angular momentum of the system evolves from L=0 to L=N, with N the number of atoms, and the ground state evolves from a fully condensed state at L=0 to the quite condensed one-vortex state at L=N, passing through a sequence of stationary states in an adiabatic evolution. Our main result reduces to the following conclusion: Among the stationary states that come out from the numerical calculation, there is one, at an intermediate critical rotation frequency for which two macro-occupied single particle wave functions play the main role, that is to say, the system cannot be represented by a unique order parameter that satisfies the Gross-Pitaevskii equation.
49_

Calculation of spin-orbit, static polarizabilities, and alignment of cold polar molecules.

Olivier Dulieu, Mireille Aymar, Johannes Deiglmayr, Roland Wester, Matthias Weidemueller.

Cold polar molecules offer exciting perspectives for studying strongly interacting cold quantum gases. Their creation in the absolute ground state through successive absorption/emission sequences relies on the detailed knowledge of their structure. Here we present new calculations of the electronic structure of all heteronuclear alkali molecules, based on effective core and polarization potentials [1] and quasi-diabatic perturbation theory [2]. Results on static dipolar polarizabilities and spin-orbit coupling functions are obtained for all pairs, all symmetries, and all internuclear distances, for the first time in most cases. Prospects for the alignment and orientation of these molecules under the influence of a combined strong laser field and a weak electrostatic field [3] are discussed.


50_

Survey of potential energy surfaces for possible sympathetic cooling systems

Piotr S. Zuchowski, Jeremy M. Hutson

In the sympathetic cooling process we lower the temperature of the molecules by the cloud of ultracold atoms. The cooling process can be efficient only if the ratio of inelastic to elastic atom-molecule collisions is sufficiently small. The crucial feature of the atom-molecule interaction potential, relevant for the knowledge of inelastic-to-elastic collisions ratio is its anisotropy. In this presentation we compare the interaction potentials between the atoms which can be trapped in magneto-optical traps and the molecules which can be cooled by Stark deceleration, i.e. ammonia, LiH, NH, OH, CO. We present the ab initio potential energy surfaces. We focus on the anisotropies of interaction potentials, and discuss the perspectives for sympathetic cooling for presented systems.
51_

On quartet states of Li₂A (A = Na, K, Rb, Cs)

Pavel Soldán

Optimized structures on the lowest electronic quartet manifold of Li₂A (A = Na, K, Rb, Cs) are presented. The strength of non-additive effects is assessed by evaluating the pairwise non-additive contributions at the optimized geometries. The trimers are also scanned at linear geometries for the presence of conical intersections. Consequences for the construction of global potential energy surfaces using many-body expansions are discussed.

52_

Potential energy surfaces of alkali trimers

R. Guérout, O. Dulieu and M. Aymar

We present preliminary results on the calculation of potential energy surfaces for alkali trimers at arbitrary geometries and symmetries. Using effective core potentials, it is possible to carry out full Configuration Interaction calculations for the valence electrons and hence accurately take into account all electronic interactions. The accuracy of our method is checked on Li₃, for which the quartet surface of the ground state is available from standard quantum chemistry methods. Results for other symmetries will be presented as well. Finally, we will also present for the first time calculations for the quartet states potential surfaces of cesium trimer.
53_

A microscope for ultracold atoms


Ultracold atoms in optical lattices are set to play a key role in applications ranging from quantum information processing to simulating the dynamics of condensed matter systems. These strongly correlated quantum systems rely on the atoms being able to tunnel between wells and interact with their neighbours. The lattices must therefore have inter-well spacings on the order of optical wavelengths. This makes detecting or addressing atoms in individual wells extremely demanding and requires very high resolution optics, as used in conventional microscopy. Here we present our plans to build a ‘microscope’ for a Rb-87 BEC in a 2-dimensional optical lattice.

54_

Fractional quantum Hall effect in optical lattices

Rebecca Palmer, Dieter Jaksch

We consider an optical lattice bosonic analogue of the fractional quantum Hall (FQH) effect, which can reach high "magnetic fields" where the discreteness of the lattice becomes important. Near simple rational numbers l/n of flux quanta per lattice cell, the single particle states become nearly periodic with period n lattice sites, and have an n fold degeneracy which acts like internal states. Standard time of flight expansion would reveal this periodicity and be able to distinguish FQH states from vortex lattice or Mott insulator states. Shot noise correlation would provide further information on the nature of the FQH states.
55_

Decoherence and entanglement induced by a quantum critical spin bath

Richard Walters, Stephen Clark, Dieter Jaksch

We investigate the dynamics of a single or two qubits coupled to a spin bath in the ground state of the Lipkin-Meshkov-Glick model. We provide results showing the dependence of the coherence loss on the phase of the bath and the number of bath spins to which the qubit (s) is coupled. The initial state is shown to be largely unaffected by the presence of the bath in the symmetric phase, whilst oscillatory behaviour-independent of the size of the bath-occurs for the broken phase. Finally, we show that the bath can induce entanglement between two initially disentangled qubits.

56_

The Quantum Hall effect in optical lattices

Sarah Al-Assam, Alexander Klein, Ben Fletcher, Ross Williams, Martin Shotter, Rebecca N. Palmer, Stephen R. Clark, Dieter Jaksch, and Christopher Foot

We explore the behaviour of interacting bosonic atoms in an optical lattice subject to a large artificial magnetic field. We show that states similar to those encountered in the fractional quantum Hall effect occur, and in the high field regime the presence of the lattice leads to interesting novel effects for the vortex lattice and quantum Hall states. First steps towards an experimental realisation of this system using a rotating optical lattice are presented. The novel experimental arrangement will provide rotation of around 1 kHz, which allows for probing of the high field regime.
57_

**Fermion- and Spin-Counting in Strongly Correlated Systems**

*Sibylle Braungardt, Aditi Sen(De), Ujjwal Sen, Roy J. Glauber, and Maciej Lewenstein*

We apply the atom counting theory to strongly correlated Fermi systems and spin models, which can be realized with ultracold atoms. The counting distributions are typically sub-Poissonian and remain smooth at quantum phase transitions, but their moments exhibit critical behavior, and characterize quantum statistical properties of the system. Moreover, more detailed characterizations are obtained with experimentally feasible spatially resolved counting distributions.

58_

**Finite-entanglement scaling with matrix product states: applications to the Bose-Hubbard like systems**

*Stephen Clark, Javier Prior and Dieter Jaksch*

Recently G. Vidal devised an extension to his matrix product state (MPS) simulation method time-evolving block decimation (TEBD) which allows infinite-sized translationally invariant 1D lattice systems to be investigated. While 1D critical systems require in principle infinite-sized MPS to be described very recent point are embedded in a finite-sized MPS approximation as a pseudo-critical anomaly which displays scaling behaviour. Following this finding we apply finite-entanglement scaling to Bose-Hubbard like systems and determine the importance of entanglement for the properties of the phase diagram in 1D such as re-entrance.
59_

Stimulating the production of ultracold molecules with laser pulses

Subhas Ghosal, Richard J Doyle, Christiane Koch and Jeremy M Hutson

The photoassociation of the ultracold $^{85}$Rb and $^{133}$Cs atoms induced by femtosecond laser pulses is analyzed by a time-dependent wave packet approach. The calculations are carried out on the manifold of the ground and two lowest-lying excited potential energy surfaces including the spin-orbit coupling between them. Preliminary results on how to modify the pulse characteristics (carrier frequency, duration, intensity) to enhance the number of photo-associated molecules are discussed and ways to optimize the production of stable $^{85}$Rb$^{133}$Cs molecules are also suggested.

60_

Phase diagram of a polarized Fermi gas at zero temperature

S. Pilati and S. Giorgini

We investigate the phase diagram of asymmetric two-component Fermi gases at zero temperature as a function of polarization and interaction strength. The equations of state of the uniform superfluid and normal phase are determined using quantum Monte Carlo simulations. We find three different mixed states, where the superfluid and the normal phase coexist in equilibrium, corresponding to phase separation between: (a) the polarized superfluid and the fully polarized normal gas, (b) the polarized superfluid and the partially polarized normal gas and (c) the unpolarized superfluid and the partially polarized normal gas.
61_

**Bosonic and Fermionic Metastable Helium near Quantum Degeneracy**

*T. Jeltes, J.M. McNamara, A.S. Tychkov, R. van Rooij, R. Rozendaal, W. Hogervorst and W. Vassen*

We report on experiments on metastable helium in Amsterdam where we have realized a BEC of more than 10 million atoms. Evaporative cooling of metastable helium-4 atoms has also been used to sympathetically cool more than 1 million fermionic helium-3 atoms into the quantum degenerate regime. In a collaboration with the metastable helium group in Orsay the ultracold gases, cooled to temperatures slightly above quantum degeneracy, are used to measure the Hanbury Brown and Twiss effect, demonstrating bunching for the bosons and antibunching for the fermions.

---

62_

**How does EOM-CCSD-R12 work?**

*Urszula Góra1, Monika Musial1, Jozef Noga2 and Stanislaw A. Kucharski1*

1. University of Silesia, Katowice, Poland  
2. Slovak Academy of Science, Bratislava, Slovakia  
3. Comenius University, Bratislava, Slovakia

The explicit inclusion of the interelectronic coordinates r12 into the wave function is a powerful means to speed up the convergence to the basis set limit. However, the methods giving accurate ground-state energies do not automatically provide the same accuracy for exitation energies.

The presented poster shows one of the way of implementation the explicitly correlated CCSD-R12 (Coupled Clusters Singles and Doubles R12) model to the excitation energy calculations. The main idea is to combine the so called standard R12 approximation with Equation of Motion (EOM) approach. The program is based on the Feynman diagram formalism and ACES II and DIRCCCR12-OS packages.
Long-range relativistic interactions between like atoms in their ground and excited states and their QED retardation

Wojciech Skomorowski and Robert Moszynski

Theory of long-range relativistic interactions between identical atoms in their ground and excited states is formulated with an emphasis on the spin-orbit interactions. It is shown that the relativistic resonant interaction between like atoms, one in the ground 1S state and the other in an excited 3L state, shows an R-(2L+1) behavior. Other contributions to the resonant relativistic potential are also considered and a complete treatment of the Casimir-Polder retardation effects within the long-wavelength quantum electrodynamics formalism is reported. Numerical results illustrating these theoretical developments are presented on the example of the calcium and strontium diatomic molecules. The accuracy of the results is proven by comparison of the computed and measured lifetimes for the electronically excited states of these atoms.