INSTITUT FOR FYSIK OG ASTRONOMI
DET NATURVIDENSKABELIGE FAKULTET
AARHUS UNIVERSITET

Few-Body Physics and Precision Experiments with Ultracold Atoms

Tuesday 22/9-2015 - Room: 1525-626

9:00-9:15	Welcome	J. Arlt
9:15-10:00	Assembling many-body systems atom by atom: A bottom-up approach	S. Jochim
10:00-10:45	An Optically Trapped Mixture of Rubidium and Meta-stable Helium Atoms	S. Knoop
10:45-11:00	Coffee break	
11:00-11:30	PhD defense: Few-body physics with ultracold potas-sium rubidium mixtures	L. Wacker
11:30-12:30	PhD defense: Discussion	L. Wacker
12:30-13:30	Lunch	
13:30-14:00	Navigating in the land of weak and strong interactions for small trapped 1D Fermi systems	N. Zinner
14:00-14:30	The HiRes experiment	R. Heck
14:30-15:00	Few- to many-body transition and the Higgs mode in a paired Fermi gas	G. Bruun
15:00-15:30	Coffee break	
15:30-16:00	Superconducting qubits and feedback	C. Andersen
16:00-16:45	Controlling open quantum systems: Tools, achievements, limitations	C. Koch
	Break (lab tours)	
18:30	Workshop dinner	

Wednesday 23/9-2015 - Room: 1525-626

9:15-10:00	Spatial gaps	D. Guéry-Odelin
10:00-10:30	PhD defense: Non-destructive imaging and feedback with ultra-cold gases	M. Gajdacz
10:30-10:45	Coffee break	
10:45-11:45	PhD defense: Discussion	M. Gajdacz
	Lunch	

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Abstracts

Assembling many-body systems atom by atom: A bottom-up approach

Selim Jochim

Physikalisches Institut, Heidelberg University

During the past years we established a technique to prepare finite samples of ultracold fermions in a tightly focused optical trap with very low entropy. So far, most of our work has been performed in a single one-dimensional tube with controllable interactions. For the extreme case of close to diverging interaction strength between the particles, a spin chain with antiferromagnetic order can be formed.

One of our long-term goals is to combine many such finite low-entropy systems into a many body system. Essential ideas to achieve this goal will be presented.

An Optically Trapped Mixture of Rubidium and Metastable Helium Atoms

Steven Knoop

L*aserLaB, Department of Physics and Astronomy, VU University Amsterdam*

I will report on our efforts to realize an ultracold mixture of ^{87}Rb and metastable triplet ^{4}He (^{4}He*) in an optical dipole trap. Our cooling scheme is based on forced evaporative cooling in a quadrupole magnetic trap and subsequent transfer to a single beam optical dipole trap (ODT). We have realized a Bose-Einstein condensate (BEC) of ^{87}Rb in the F=2, m_F=2 hyperfine substate in the hybrid trap [1], and recently we have obtained a ^{4}He* BEC following a similar scheme [2]. Currently we are working on simultaneous loading of ^{4}He* and ^{87}Rb in the ODT. In this talk I will discuss the prospects and challenges of ultracold mixture of alkali-metal and metastable helium atoms.

[1] H. P. Mishra, A. S. Flores, W. Vassen, S. Knoop, Eur. Phys. J. D 69, 52 (2015)

[2] A. S. Flores, H. P. Mishra, W. Vassen, S. Knoop, arXiv:1508.04019

Navigating in the land of weak and strong interactions for small trapped 1D Fermi systems

Nikolaj Zinner

Institut for Fysik og Astronomi, Aarhus Universitet

In this talk I will try to show how one can use the recently obtained exact solutions of the strongly interacting 1D trapped Fermi system to capture the physics of these systems for any interacting strength.

Few- to many-body transition and the Higgs mode in a paired Fermi gas

Georg Bruun

Institut for Fysik og Astronomi, Aarhus Universitet

We show that an undamped few-body precursor of the Higgs mode can be clearly identified and investigated in a two-component harmonically trapped Fermi gas. In the many-body limit, the Higgs mode corresponds to vibrations in the magnitude of a classical field that induce a collective motion of particles. We demonstrate by exact diagonalisation that the few-body precursor of this mode corresponds to coherent excitations of time-reversed pairs across the energy gap. The mode has a minimum energy in a crossover region, which is the remnant of a sharp thermodynamic quantum phase transition between a normal and a super fluid phase. We demonstrate that this mode can be selectively excited and unequivocally identified using cold atoms in microtraps.

Superconducting qubits and feedback

Christian Kraglund Andersen

Institut for Fysik og Astronomi, Aarhus Universitet

The field of superconducting resonators and qubits, has recently become a promising candidate for quantum information processing due to dramatic improvements in the quantum technologies. In this talk I will briefly present how these qubit-systems can be operated and controlled. Traditional control of superconducting system may, however, become infeasible for large-scale system. To circumvent some of the present challenges I will discuss some of our recent works concerning an all-cryogenics feedback system that operates both a qubit and a classical feedback system with the same microscopic technology. I will also briefly discuss how such these ideas naturally generalises to many qubit systems.

Controlling open quantum systems: Tools, achievements, limitations

Christiane Koch

Institute of Physics , University of Kassel

Quantum control is an important prerequisite for quantum devices. A major obstacle is the fact that a quantum system can never completely be isolated from its environment. The interaction with the environment causes decoherence. Optimal control theory is a tool that can be used to identify control strategies in the presence of decoherence. I will show how to adapt optimal control theory to quantum information tasks for open quantum systems and present examples for cold atoms and superconducting qubits.

The perspective on decoherence only as the adversary of quantum control is nevertheless too narrow. There exist a number of control tasks, such as cooling and measurement, that can only be achieved by an interplay of control and dissipation. I will show how to utilize optimal control theory to derive efficient cooling strategies for molecular vibrations where the timescales of coherent dynamics and dissipation are very different. Another opportunity for open system control, less obvious than cooling, arises from a coupling to the environment that results in non-Markovian dynamics. I will discuss how non-Markovianity of the open system time evolution can be exploited for control, using a superconducting phase circuit as example.

Spatial gaps

David Guéry-Odelin

Laboratoire de Collisions - Agrégats - Réactivité, Université Paul Sabatier - Toulouse 3

I will introduce a few experiments of atom optics that we have performed in guided environment using a finite size optical lattice. I will present the use of the optical lattice as a distributed Bragg reflector for matter waves. Actually, the envelope of the optical lattice projects in position space the gaps of the lattice. As a result Landau Zener transitions become effective tunnel barriers in real space, commonly referred to as spatial gaps. Using a symmetric envelope, we have realized a matter wave cavity with walls provided by spatial gaps and having an energy dependent reflectivity. In this system, we can observe directly a single tunneling event. We will discuss the possible applications of this technique including the design of landscape of tunnel barriers, the realization of a mode locked atom laser or the design of arrays of coupled cavities. Interestingly, the coupling between the cavities can be tuned by time dependent modulation that drives interband transitions. We will provide a few examples that we have explored numerically.