ESF/PESC Exploratory Workshop

COLLISIONS IN ATOM TRAPS (CATS)

Sønderborg, Denmark, April 7th-11th 2002

Executive summary

Introduction

The ability to cool, trap and manipulate atoms, culminating in the successful formation of Bose-Einstein condensates, is one of the most exciting advances in the field of atomic and molecular physics in the late 20th century. Such experimental advances are pioneering new instrumentation on the atomic and nanoscale (e.g. development of atomic interferometers) and has led to orders of magnitude improvement in our ability to measure time while opening the possibility of new technologies of atom lasers, quantum computing, quantum cryptography and teleportation.

To date the role of collisions in atom traps has been viewed mainly as detrimental - leading to trap losses- but recently experiments and new theoretical formalisms suggest that collisions between trapped atoms, between trapped atoms and external stimulation phenomena and between cold atoms and external surface media may lead to new physico-chemical phenomena that may in turn lead to exciting new fields of study in atomic, molecular, optical and condensed matter physics.

The aim of the workshop was to organize discussions and contacts between experts in the fields of trapped atoms, laser physics, collision physics, spectroscopy and condensed matter to discuss future studies of collisions phenomena in atom traps. Five broad themes were discussed:

1.The role intra-atomic collisions in the formation of Bose-Einstein condensates
2. Photoassociation leading to molecular formation.
3. External stimulation of cold atomic targets by collisional partners
4. The formation and manipulation of optical lattices and their comparison with conventional condensed matter and
5 Applications of cold atom technology and its limitations due to collisional phenomena.

Further details of the presented talks and discussion are provided in the Scientific report however we summarise the main conclusions below.

Scientific Review

The workshop started with a review of the prospects for achieving **Bose-Einstein condensates** beyond alkali atoms (metastable neon or helium) systems in which Penning ionization is suppressed by polarization techniques well known in traditional collision physics. In order to describe BEC, macroscopic scattering functions are necessary. Modelling of a BEC, or a degenerate Fermi gas, therefore requires low energy scattering data that is traditionally the preserve of the scattering community, the transfer of information and skills between the low energy collision community and the BEC community was highlighted. The importance of interactions between the condensate and the surrounding thermal cloud was discussed in relation to the formation and density of BECs. Collisions in **mixed alkali traps**, with the aim of making mixed condensates or creating heteronuclear cold dimers, was also reviewed. Sympathetic cooling, relying on collisions between two species, one colder than the other would seem to be a very powerful technique capable of achieving BEC in non alkali systems.

The workshop reviewed the topic of **cold collisions** discussing how the concepts developed for electron-atom or electron molecule collisions at low energies (scattering length, Feshbach resonances, threshold laws, virtual states, the Ramsauer effect and the concept of time delay) may be introduced into the field of cold atom physics. Traditional collision techniques using beams of electrons, ions or atoms, with a target made of *cold atoms* seem capable of producing **accurate collision data** for comparison with theory and with practical importance.

The formation and mnaipulation of **optical lattices** allow analogies to be made between cold atom physics and conventional condensed matter. In such lattices the interatomic collisions are taking place in the presence of an external field. Analogies between a 3-level system and the photoassociation problem was discussed.

The fomation of cold molecules (and thence molecular condenssates) is currently a topic of major research bothi n Europe and the United Sates. **Making molecules, decelerating them, trapping them** was intensively discussed. The combination of advanced techniques such as molecular beams and deceleration (from particle accelerators) are a good example of the advantage of interdisiplinary research. The formation of dimers by **photoassociation** may be viewed as the inverse of the well-known half-collisions processes well studied in the molecular and chemcial physics community. Accurate collision data can be extracted from the spectra of cold molecules, while threshold laws are fitted to the line shapes.

THE FUTURE

1. The problem of **ion detection and electron detection** in experiments with atom traps or BEC, necessitates a **transfer of technology** from the collision field to the cold atom field. The combination of technologies (beam+trap+laser+time of flight detection) seems very promising.

2. Cold atoms or cold molecules in traps should be used to determine precise collision data, such as photodissociation cross sections, which are not known accurately at present and are needed in other fields such as astrophysics or atmospheric physics.

3. The **sympathetic cooling method** should be developed further since collisions between cold atoms and molecules are expected to allow the formation of a **molecular condensate**. This methodology sahould be ocmapred with the alternative use of **photoassociation in an atomic condensate** .

4. For such projects, **collision data are essential**: how to extract them from accurate spectroscopy, or compute them will require much effort and **close collaboration** between the electorn/atom- atom/molecule collision community and the BEC /cold atom community. More elaborate discussions between experts in the collision field one the one hand, cold atoms or BEC field on the other, should decide how Ramsauer-Townsend effect can be visible, where virtual states could be an useful concept, how to scan a resonance. Extracting accurate cross sections from trap loss measurements or other trap data should be revisited.

5. Collisions in external fields must be well understood to interpret experiments in microtraps or optical lattices. The link with the field of coherent control, where the laser pulses are shaped in order to optimize products in a chosen reaction channel, should be established. Presently the experts in that field are mostly in the chemistry community.

6. Applications are foreseen in the direction of nanocontrol of matter, quantum computing, building molecules atom by atom, chemistry and photochemistry at ultracold temperatures. The development of interdisciplinary research teams and collaboration of optical community and the collision physics communities (as brought together by this workshop) are therefore vital to the successful development of this exciting field of scientific research.

Final Programme

Sunday 7th April 2002

Time	
up to 18:00	Participants arrive
18:00-19:00	*Dinner*

Monday 8th April 2002

	Session One	**Chair:**	*Nigel Mason*
Time	**Title of Talk**		**Speaker**
09:30-09:40	Introduction to Workshop		Massimo Martinelli
09:40-10:20	Metastable neon: Cold Collisions and BEC		Herman Beijerinck
10:20-10:50	*Coffee*		
10:50-11:30	Rubidium condensates for atomic physics studies		Ennio Arimondo
11:30-12:10	Phase properties of Bose-Einstein Condensates		Karl Sengstock
12:10-13:00	*Lunch*		

	Session Two	**Chair:**	*Françoise Masnou-Seeuws*
Time	**Title of Talk**		**Speaker**
14:00-14:40	Rotons in a Bose-Einstein condensate		Duncan O'Dell
14:40-15:20	Studies of cold magnesium atoms		Jan Thomsen
15:20-15:50	*Coffee*		
15:50-16:30	External stimulation of atom traps		Nigel Mason
16:30-17:10	Cold electrons, time delays and molecules		David Field
18:00-19:00	*Dinner*		

Tuesday 9th April 2002

	Session Three	**Chair:**	*Ennio Arimondo*
Time	**Title of Talk**		**Speaker**
09:00-09:40	Interaction processes in a mixture of ultracold gases		Matthias Weidemüller
09:40-10:20	Simultaneous trapping of Na atoms in a two-species MOT and their interactions		Laurentius Windholz
10:20-10:50	*Coffee*		
10:50-11:30	Structure of Trapped Degenerate Fermi Gases including s- and p-Wave		Robert Roth
11:30-12:10	Elastic and Inelastic collisions in an ultra cold metastable helium gas		Jérémie Léonard
12:10-13:00	*Lunch*		

Tuesday 9th April 2002

Session Four **Chair:** *Herman Beijerinck*

Time	Title of Talk	Speaker
14:00-14:40	Formation of ultracold molecules via photoassociation of laser cooled atoms: theoretical developments	Françoise Masnou-Seeuws
14:40-15:20	Formation, accumulation and trapping of cold molecules	Pierre Pillet
15:20-15:50	*Coffee*	
15:50-16:30	Deceleration and trapping of neutral dipolar molecules	Gerard Meijer
16:30-17:10	Fermionic lithium atoms in a resonator-enhanced dipole trap	Allard Mosk
18:00-19:00	*Conference Dinner*	

Wednesday 10th April 2002

Session Five **Chair:** *Laurentius Windholz*

Time	Title of Talk	Speaker
09:30-10:20	Collisions, condensates and optical Lattices	Paul Julienne
10:20-10:50	*Coffee*	
10:50-11:30	Quantum-state control in non-dissipative optical lattices	David Meacher
11:30-12:10	Cold collisions between atoms in near resonant optical lattices	Jyrki Piilo
12:10-13:00	*Lunch*	

Session Six **Chair:** *Lars Bojer-Madsen*

Time	Title of Talk	Speaker
14:00-14:40	EIT enhanced optical nonlinearities in cold atoms	Andrew Greentree
14:40-15:20	COLTRIMS with a MOT target: Fraunhofer diffraction of matter waves	Mette Machholm
15:20-15:50	*Coffee*	
15:50-16:30	Cooling of Internal and External Degrees of Freedom in Heteronuclear Molecular Ions	Ivan Vogelius
16:30-17:10	Discussion	
18:00-19:00	*Dinner*	

Thursday 11th April 2002

Session Seven

Time	Title of Talk
09:30-10:20	Discussion and report of meeting
10:20-10:50	*Coffee*
10:50-12:00	Discussion and report of meeting
12:00-13:00	*Lunch*
13:00-	*Participants depart Sandbjerg*

Assessment of the Results of the CATS workshop

This workshop was a unique event since it was the first meeting to discuss exclusively the role of collisions with cold atoms, bringing together for the first time researchers in traditional collision physics with trapped atom researchers. The meeting revealed the similarities between these two areas of modern physics and highlighted how one community can (and should) learn from the other. For Younger researchers this was a particularly fruitful interaction as they had not had the opportunity to interact with members of the other community since conferences and workshops they usually attended were much narrower in their scope.

Currently the US is regarded as the international leader in cold atom physics but an increasing number of European groups have been established in the past ten years and today European research in cold atoms/molecules and optical lattices is developing rapidly. In contrast Europe is preeminent in the study of collision physics (both experimental and theoretical) a community that is lacking in the United States. Since the future of this area will increasingly require knowledge transfer from the collision community to the cold atom community Europe is seemingly well placed to lead the next generation of experimental studies involving cold molecules, non alkaline BECs and hence the application of cold atom/molecule physics towards the nanocontrol of matter, quantum computing, building molecules atom by atom and photochemistry at ultracold temperatures.

However for such collaboration to develop (and grow for example by bringing the chemical community into the research field) forums for cross disciplinary discussions and technology/skills transfer are needed. The ESF workshop programme together with the ESF scientific networks and scientific programmes provide opportunities for developing (continuing) these vital collaborations while future EC Framework funding provide another. The participants at the meeting agreed that these research opportunities should be pursued and application prepared to these respective bodies in the near future.

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(those marked with an asterix are younger scientists)

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