Scientific report on the
CAMS: Conference on Atoms and Molecules near Surfaces

Internationales Wissenschaftsforum Heidelberg,
Heidelberg, Germany, 4-8 April 2005.

Summary

The scientific content of the conference was the physics of atoms and molecules near surfaces. More in detail, the conference concerned the effects on the atoms and molecules induced by the presence of an object.
The mentioned effects are changes in the behaviour of the particles such as variations in energy levels and their lifetime, as well as larger scale effects such as attractive and repulsive forces.
These issues are presently studied throughout the world, with a wide variety of techniques, most them being discussed at the conference.

The purpose of the conference was to bring together specialists in these subjects to open discussions between the separated fields. For that purpose the majority of the speakers were invited, the contributed talks and posters were predominantly from young researchers.

Throughout the conference there were many discussions among the participants, during the talks as well as in the breaks and especially at the poster sessions.

Scientific report

The main format of the conference was of single sessions, all grouped around specific themes per day.

A tutorial lecture opened the day for each particular main theme, to be followed by more detailed contributions. Theoretical talks and experimental talks were mixed, with emphasis on the experimental aspects.
As a consequence, the focus of the conference was not primarily on the interactions themselves, but rather on how to prepare and study a sample of particles close to the desired surface. In these sections, several techniques for trapping and manipulating atoms and molecules were presented.

In view of the small energy scales concerned here, most experiments dealt with cold and ultra-cold atoms and Bose-Einstein condensates (BECs) to minimise thermal noise masking signals. Degenerate Fermi gases were occasionally mentioned, but not used in the presented experiments.

The following is a summary of the presentations, details will be published in the CAMS proceedings, to be published by the Institute of Physics as a volume of the Journal of Physics: Conference Series, available online.

Monday 4.4. dealt with a theoretical introduction into and refreshment of the main physics themes of the conference: the Casimir-Polder interaction and the Van der Waals forces. The subsequent talks discussed experiments with atomic beams passing surfaces at grazing incidence. Different techniques allowed to use the quantum reflection off these surfaces to map energy bands in the surfaces and super-reflective mirrors for atoms of selected energy classes.
Interferometer set-ups studied the transition from the quantum-to-classical world with atoms and molecules, where the energy shift due to the interaction of the passing particles close to the material gratings introduced clearly measurable phase shifts. Quantum reflections and field inhomogeneities (both spatially and temporally) were studied with BECs as well. The results here proved that the general physics in this domain is well understood and that the experimental control is such that deviations of the theories may be hunted.

Tue. 5.4. was reserved for either the conference excursion and –dinner, or for the Mid-Term review of the EU-5th Framework training network FASTNet. In the network, the contacts between and the integration of the various branches of studies into atom-surface interaction have been combined for some years.
The topics of this day have been covered in more detail by the invited presentations of the respective FASTNet partners on the other days.

Wed 6.4. saw the focus on atom chips; miniaturised (electro-) magnetic traps, based on surface mounted structures. All contributions discussed the effects of stray magnetic or electric fields on the integrity and life time of BECs, most notably the fact that minute deviations from a straight current path cause potential changes up to nK. The exact cause for the current deviations is still unclear, however it is recognised that the material properties of the conductors on the atom chip play the main role, such as the shape details of the wires and the graininess of the material.
The thickness and conductivity of the conductor material are also of interest, since they determine the sensitivity of the atoms for noise, both from thermal conductance noise (Johnson noise) as from radiation noise coupled into the wires.
A strong accent was put on these effects as problems for atom interferometry and quantum information processing. Thus also different trap properties for splitting and manipulating BECs in double- or multiple well potentials were debated.
The novel result of a BEC created in a permanent-magnet atom chip (based on video-tape) was presented by the group of the Imperial College London (UK). This chip did show fragmentation of the BEC, but not the noise-amplification (or antenna-) effect, as was indeed theoretically predicted.
At the end of the day lab tours through the Heidelberg labs enabled more technical discussions and exchange of ideas.

Tue 7.4. concerned different optical techniques for diagnosing, probing and manipulating atoms, molecules and nanoparticles near surfaces. Here a variety of scanning probe techniques and different spectroscopic techniques were presented.
The optical aspects of gold nano-particles were both treated as having an influence on the emission chararacteristics of molecule in their neighbourhood as well as antennae for radiation at different wavelengths; here it appeared that the size of nano-droplets can be tuned

to a given value by irradiating them with different wave lengths, thus performing a type of spectroscopy.
A different branch of near-surface spectroscopy was presented in a series of talks where the evanescent field of laser light, reflected internally in a prism was used. The response of absorption and/or scattering of the light by the atoms was measured and analysed, giving evidence for energy level shifts.
A similar set-up creates the evanescent wave traps using the light field leaking out into the vacuum outside the prism for trapping and manipulating the atoms. When the wavelength of the light is shorter than the resonance wavelength of the atom, the atoms are repelled out of the beam. For longer wavelengths (red detuning), the atoms are attracted towards regions of higher intensity. Combining both red and blue detuned light fields with different intensity distributions enables diverse trapping potentials. The traps have also been used for the creation and manipulation of 2D BECs. A new development is the planned use of the evanescent fields around optical fibres and the fields created by sub-wavelength structures. Such structures allow to manipulate atoms, and possibly BECs in novel ways.
Studies on light induced atomic desorption (LIAD) were presented; the mechanism behind the process is still not fully understood. The desorption process however takes place for most alkalides and it releases sufficient atoms to be used for loading magneto-optical traps.

Thu. 7.4. also hosted two talks on using the surface of liquid helium for trapping and storing particles: electrons and hydrogen atoms. The former system is based on the induction of mirror charges, thus being closely related to the origin of Van der Waals forces. The system shows various crystalline orderings and can be used to model quantum electro dynamics in 2D electron gases in semiconductors.
The latter system can be brought to Bose condense into a large 2D quantum degenerate system, where density fluctuations and many-body processes inside the BECs can be studied.

Fri. 8.4. carried as theme the nano-structuring of surfaces and detection of the effects of nano-structures on light and nano-particles.
Scanning probe techniques proved effective in creating traps for atoms and molecules due to surface structures such as crystal-plane ridges and mismatches. The techniques also allowed to initiate and observe chemical reactions of trapped molecules, even time resolved.
Sub-wavelength structures created on surfaces proved to enable tighter focused and more abruptly structured light beams than with traditional optics, which should be used to create structured atomic deposition.
The latter is a topic with a proclaimed industrial interest, namely deterministic and structured doping of semiconductors and nano-scale device creation by virtue of controlled atom deposition via atom lithography. The CAMS conference saw the first presentation of the spectroscopic details of erbium that can be used for structured doping, as well as for laser cooling and trapping, possibly also for Bose-Einstein condensation.
The conference ended with a contributed talks-session covering all conference topics again in succession.

In all, it was shown that Bose-Einstein condensates are possibly the most sensitive tools to study atom-surface interactions due to the freezing out of nearly all thermal noise. The surface interactions generally reduce the potential towards the surface, thus reducing the lifetime of the atoms in the trap. At the same time the overall trap shape is affected causing different trapping parameters. The deisred information can thus be read from small changes in oscillation frequencies of the atom clouds in trap held at different distances from the surface.

These two techniques have enabled measurements of the Casimir-Polder force up to 5 µm away from the surface, further than possible with any other technique to date and at a precision approaching the one needed to detect modification due to thermal radiation.
The deviation of the magnetic potentials generated in atom chips have been mapped out to a sensitivity level of 4 nT, at a spatial resolution of 3 µm by monitoring density distributions and the breaking up of Bose-Einstein condensates into small fragments. This sensitive potential mapping cannot be done without BECs.
On the other hand, the details of the processes and strenghs of the different interactions must be known for the techniques to be used for studying the gases in the highly flexible trapping devices, including miniature probes and optical techniques to perform quantum information processing and to study quantum electrodynamics.

The conference set a new stage for the researchers in the ultra-cold atom and moladular physics community in that it presented a wide variety of techniques and views on atom, molecule and surface interactions.

Results of the conference and its previewed impact

The main results of the conference were the heightened awareness of the participants of the different fields and techniques used to investigate and possibly use the interactions between atoms, molecules and surfaces of various kinds. A meeting of this scope and of this level of the participants has never been held, to the knowledge of both the organisers and the participants.

Several participants noted that the meeting came at the right time; the progress in micro-trapping (first and foremost in the field of the atom chip) has been astounding: the first devices were reported in 1999, the first BECs in atom chips in 2001, now (2005) there are well over a dozen groups in the world working with the technique.
In the realm of scanning probe microscopy the observation and monitoring of surface induced chemical reactions of gaseous reaction partners has taken off, with a strong industrial interest into the operation of catalytic conversion processes.

Since approximately half the audience consisted of young researchers (PhD-students and PostDocs) an expected and desired consequence of the conference is that researchers will transfer more easily to another presented branches of physics, thus causing a wider spread of specialised knowledge

Directly tangible results of the conference have yet to materialise, although the conference proceedings will certainly spark more interest in the field.

Here, it might be noted that the EU Program Officer in charge of the FASTNet network (S. Davies) was present at the CAMS on Tue. 5.4. and that he was highly commendable on the interaction between and integration of the nine FASTNet partners, which combined cover approximately half the topics discussed during the CAMS. He foresaw a bright future for the interdisciplinary field and its researchers.

Time	Sun. 3.4.	Mon. 4.4.	Tue. 5.4.		Wed. 6.4.	Thu. 7.4.	Fri. 8.4.	Time
	Arrival	Interaction	FASTnet non-members	FASTnet-Members	Atom Chips	Optics near surfaces	Surface structuring	
	Opening	Contributed Talks	Conf. Excursion	Mid-Term Review	Lab-Tours	Liquid Helium as surface	Contributed Talks	
		Posters		Conf. Dinner	Festrede / BBQ party	Posters	Departure	
08:30		Morning coffee at IWH	Morning coffee at IWH	Morning coffee at IWH	Morning coffee at IWH	Morning coffee at IWH	Morning coffee at IWH	08:30
09:00		J. Babb	Assembling at Neckarmuenzplatz, HD	EC Introduction / Coordinator: S. Davies / J. Weiner	P. Krüger	V. Sandoghdar	E. Meyer	09:00
09:30			Bus trip to Schloss Schwetzingen			F. Träger		09:30
10:00		Coffee break	Guided tour of Schloss	Coffee break	Coffee break		Coffee break	10:00
10:30		M. de Kieviet			C. Henkel	Coffee break	K.-H. Rieder	10:30
11:00				Toulouse: J. Weiner / C. O'Dwyer		V. Bordo		11:00
11:30		F. Shimizu	Coffee on own accord	Villetaneuse: M. Ducloy / P. Todorov	Y. Colombe		J. Weiner	11:30
12:00		Lunch on own accord	Guided tour of Gardens	Imperial: E. Hinds / I. Llorente-Garcia	Lunch on own accord	D. Bloch	Lunch on own accord	12:00
12:30				Bonn: D. Meschede / Y. Louyer		Lunch on own accord		12:30
13:00				Lunch on own accord				13:00
13:30			Bus trip back to Neckarmuenzplatz, HD					13:30
14:00		A. Cronin	Afternoon free:	Siena: L. Moi / T. Kawalec	J. Fortagh	L. Moi	D. Meschede	14:00
14:30		M. Arndt	Heidelberg Altstadt? / Schloss Heidelberg?	Odense: H.G. Rubahn / R. Frese	E. Hinds	H. Perrin	J. McClelland	14:30
15:00		T. Pasquini	Boating the Neckar?	Heidelberg: J. Schmiedmayer / L. Della Pietra	C. Westbrook	R. Grimm	F. Besenbacher	15:00
15:30		Coffee break	Lab / Group visits?	Coffee break	Coffee break	Coffee break	Coffee break	15:30
16:00	Opening reception	D. Harber	- Physikalisches Institut - Oberthaler-Group	Potsdam: C. Henkel / A. Negretti	Walk to Phys. Inst. Lab-Tours	S. Vasiliev	W. Allison	16:00
16:30		H. Abele	- MPI-Kernphysik - MPI-Astrophysik	Innsbruck: R. Grimm / B. Engeser	Physikalisches Institut		C. Huang C. Sinclair	16:30
	IWH	J. Perreault	- EMBL		Atom Chips	P. Leiderer	N. Bigelow	
17:00		J.-C. Karam	- etc.	EC + Young Researchers: S. Davies + YRs	(Schmiedmayer)		J. Nes	17:00
		R. Folman					Final remarks	
17:30				YR Spokesperson: S. Eriksson	Atom Spinecho		Departure	17:30
				Open Discussion / EC feedback: All	(De Kieviet)			
18:00		Dinner on own accord			G. Meijer *	Dinner on own accord	Dinner on own accord	18:00
				Perspectives: S. Davies	at:			
18:30	Heidelberg by night ?				Physikalishes Institut		Heidelberg by night ?	18:30
19:00			CONFERENCE DINNER at: Haus Buhl		Followed by Barbecue-party * at: Physikalishes Institut			19:00
19:30		HAW open for putting up the posters				HAW open for putting up the posters		19:30
20:00		POSTERS at: Heidelberger Akademie der Wissenschaften (HAW)				POSTERS at: Heidelberger Akademie der Wissenschaften (HAW)		20:00
20:30								20:30
21:00								21:00
21:30								21:30
22:00					*: In collaboration with:			22:00
		Posters can remain at			XIV. Heidelberger			
22:30		HAW for next session.	Closes at 0:00		Graduiertenkurse Physik			22:30