

Scientific Report

**XX International Conference  
on Atomic Physics**

in Innsbruck, Austria

16 – 21 July 2006

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## 1 Summary

The biyearly International Conference on Atomic Physics (ICAP) is one of the most prestigious conferences in the field of atomic physics. This years 20<sup>th</sup> ICAP took place from July 16<sup>th</sup> to 21<sup>st</sup> in Innsbruck, Austria. Selected top researchers including eight Nobel Prize Laureates presented latest achievements in atomic physics including precision spectroscopy, ultra-cold atoms and molecules, and quantum information processing. The outstanding quality of the scientific programm attracted more than 800 participants, 300 more than originally anticipated.

The goal of this conference is to mediate very recent research achievements to the community and to serve as a platform for scientific exchange. Therefore, the 800 European and international participants encompassed researchers at all levels, ranging from advanced graduate students to Nobel Prize winners. The International Conference on Atomic Physics traditionally features only invited speakers that are selected by the program committee. We had eleven topical sessions that were preluded by well-established researchers who introduced the topic in breadth, including, but not limited to their own recent accomplishments. The talks during the remainder of each session focussed on research highlights in the field of the past two years. Especially high-potential young researchers became the opportunity to present their outstanding scientific results to the community in these sessions. In addition, we had three more sessions with an emphasis on the history and an overview of the field of atomic physics, and two public talks, all given by distinguished Nobel Laureates. In total, we had 50 invited speakers. The oral presentations of invited speakers have been complemented by poster presentations on latest developments in the field to which all participants could contribute during three very busy poster sessions.

## 2 Scientific Content

The scientific program of the conference covered a wide variety of topics within the field of atomic physics.

The conference started with a historical session on the field of atomic physics, featuring presentations of senior scientists and Nobel Prize Laureates such as Norman Ramsey from Harvard University, USA (NP 1989), Roy Glauber from Harvard University, USA (NP 2005), Jan Hall from JILA in Boulder, USA (NP 2005) and Claude Cohen-Tanoudji from ENS in Paris, France (NP 1997).

The topic of the session **Fundamental Physics and precision measurements I** was introduced by Nobel Prize Laureate Theodore Hänsch (NP 2005) from MPQ in Garching, Germany, with a talk on “Fundamental physics and precision measurements”. Victor Flambaum from the University of South Wales, Australia, continued with his talk on “Effects of variation of fundamental constants from Big Bang to atomic clocks”, summarizing recent theoretical work and experimental observations on a possible change in the fine-structure constant  $\alpha$ . Latest results on highly charged ions in Penning traps at GSI in Darmstadt, Germany, were presented by H.J. Kluge in his presentation “Precision experiments with stored and cooled highly charged ions”.

The next session **Fundamental physics and precision measurements II** was introduced by Jun Ye from JILA in Boulder, Colorado with his talk “Precision measurement based on ultracold atoms and cold molecules” on atomic clocks and molecules with an emphasis on latest developments and absolute frequency measurements in optical lattice-based neutral atom clocks. Helen Margolis from NPL, UK, reported about recent work on ion based optical clocks in her talk “Trapped ion optical clocks at NPL”. Wim Ubachs from the Laser Centre Vrije Universiteit Amsterdam, The Netherlands, reported on a precision measurement of the proton-to-electron mass ration over cosmological time scale in his presentation “Precision spectroscopy of  $H_2$  and a possible variation of  $m_p/m_e$  over cosmological time”.

The three speakers of the **Theory** session discussed various aspects of atomic and molecular physics. Masahito Ueda from the Tokyo Institute of Technology, Japan, gave a talk on “Symmetry Breaking in Bose-Einstein Condensates”. Paul Julienne from NIST in Gaithersburg, USA, reported on “Simple theoretical models for resonant cold atom interactions”, in particular optical control of Feshbach resonances and atom-atom interaction. Vladimir Shabaev from St. Petersburg State University, Russia, presented Quantum Electrodynamics (QED) calculations for highly-charged ions in his talk “Quantum electrodynamics of heavy ions and atoms”.

The Nobel Prize Laureate Carl Wieman (NP 2001) from University of Colorado in Boulder, USA, gave an extremely well-visited **evening lecture** on scientific teaching. In his talk “Education in the 21st Century; a scientific approach to science education”, he broke with traditional approaches to science teaching and presented scientific data supporting his claim that online simulations allow students to gain better insight into scientific material.

The session **Atomic Bose Gases in Low Dimensions** was introduced by Jean Dalibard from Laboratoire Kastler Brossel in Paris, France, with his talk “Atomic Bose

Gases in Low Dimensions” in which he discussed recent achievements of various groups working on low-dimensional aspects of Bose-Einstein Condensation, in particular the formation of vortex pairs in a two-dimensional atomic gas. Markus Oberthaler from University of Heidelberg, Germany, reported in his presentation “Bosonic Josephson Junction at finite temperature” on ultra-low temperature measurements utilizing phase fluctuations in a Bose gas. “Interference between fluctuating condensates” was the title of Eugene Demler’s (Harvard University, USA) talk. He discussed phase properties of interfering Bose-Einstein Condensates.

**Fermi gases** was the topic of the following session, introduced by Nobel Prize Laureate Wolfgang Ketterle (NP 2001) from MIT in Boston, USA. He gave a talk on “Superfluidity in a Gas of Fermionic Atoms”, reporting on recent work on two-component fermi systems with imbalanced population. Klaus Sengstock from University of Hamburg, Germany, discussed properties of Fermi-Bose mixtures in optical lattices in his talk “Fermi-Bose mixtures in three-dimensional optical lattices”. Stefano Giorgini from the University of Trento, Italy, presented a theoretical study of “Fermi gas in the BCS-BEC crossover: a quantum Monte Carlo study”.

The first **Hot Topics** session covered topics ranging from ultra-cold atoms in three-dimensional optical lattices to light induced cooling of microscopic objects and novel quantum phases in cold polar molecules.

The session **Quantum information processing with atoms and ions** was introduced by David Wineland from NIST in Boulder, USA, with a talk on “Quantum information processing with atoms and ions”. He summarized work on quantum computation with trapped ions and applications in the field of precision metrology. Along the same lines, Christian Roos from the University of Innsbruck, Austria, reported on a precision measurement of the electric quadrupole moment of a trapped ion using “Entangled states for precision spectroscopy”. Misha Lukin from Harvard University, USA, reported on a new approach to quantum computing using “Quantum bits and quantum wires in solid state”.

Gerhard Rempe from MPQ in Garching, Germany introduced the session **Quantum optics and cavity QED with atoms** with a talk on “Cavity QED: A Toolbox For Achieving Full Control Over Massive and Light Particles”, summarizing recent achievements and possible applications of atoms trapped inside a high-finesse cavity. Ground state cooling of atoms inside a cavity and coupling of an atom to a high-Q toroidal microresonator was reported by Jeff Kimble from the California Institute of Technology, Pasadena, USA, in his talk “Quantum Optics with Atomic Ensembles and Single Atoms

in Cavities”. Robert Schoelkopf gave a talk on “Circuit QED and the Prospects for Quantum Circuits with Polar Molecules” in which he discussed how circuit QED and cold polar molecules can be used to perform quantum non-demolition measurements and how to store quantum information in such a system.

During a **public evening lecture** in a crowded lecture hall, Nobel Prize Laureate William Phillips (NP 1997) gave a spectacular performance on “Time, Einstein, and the coolest stuff in the universe”.

The session **Cold molecules** was introduced by John Doyle from Harvard University, Cambridge, USA, with his overview of achievements and applications in the field of “Cold Polar Molecules”. Gerard Meijer from the Fritz-Haber-Institute in Berlin, Germany, gave a talk on “Slowing and trapping of polar molecules”, summarizing his laboratory’s efforts towards a cold and trapped molecular sample using electrostatic deceleration and trapping techniques. David DeMille from Yale University in New Haven, USA, reported on progress towards ultra-cold molecules in the ro-vibrational ground state for precision spectroscopy in his talk “Production of ultracold polar molecules from atoms”.

Jakob Reichel from ENS in Paris, France, introduced the session **Chip traps for atoms, ions and molecules** with a talk on “Atom Chip applications”. He summarized recent advances in the neutral atom chip trap technology and applications in quantum optics and sensitive surface sensors. An experiment with sympathetically cooled fermionic atoms on a chip was presented by Joseph Thywissen from the University of Toronto, Canada, in his talk “Atom chips for neutral fermions”. Richard Slusher from Lucent Laboratories, Murray Hill, USA gave a presentation on “Scalable Ion Traps with Monolithically Integrated CMOS Controls” in which he discussed the latest ion chip trap technology developed by Lucent in collaboration with laboratories around the world.

The topics of the **Hot topics II** session ranged from the experimental evidence of Efimov states and pair correlation measurements in ultra-cold atoms via quantum teleportation between light and matter to precision measurements of the electron electric dipole moment, its magnetic moment and the fine-structure constant.

The next session was dedicated to **Attosecond physics with atoms**. Anne L’Huillier from Lund University, Sweden, introduced the topic by reviewing recent achievements and applications of atto-second pulses in atomic physics in her talk “Atomic Physics with Attosecond Pulses”. Reinhard Kienberger from MPQ in Garching, Germany, reported on “Single attosecond pulses and first applications” in which he discussed the dynamics of the photoionization process of xenon. The last talk of this session was given by Jon Marangos from Imperial College in London, UK, “Probing attosecond dynamics by chirp

encoded electron recollisions”, in which he reported on experimental investigation of the ultra-fast dynamics in molecular hydrogen and deuterium.

The final session **Atoms in optical lattices** of the conference was introduced by Tilman Esslinger from ETH Zürich, Switzerland, with a talk on “A Lab in a Trap: Fermions, Molecules and Bose-Fermi mixtures in an Optical Lattice”. Immanuel Bloch from the University of Mainz reported in his talk “Strongly correlated atoms in optical lattices” on latest achievements in his lab, including the observation of a shell structure of atoms in optical lattices and correlation measurements of fermionic and bosonic atom species. Maciej Lewenstein from Institut de Ciències Fotòniques in Barcelona, Spain, gave a presentation on “Travelling to exotic places with ultracold atomic gases” in which he summarized recent theoretical work of his group.

### 3 Assessment and Discussion

The XX International Conference on Atomic Physics was a great success. This is not only reflected by a record participant number, exceeding 800, but also by feedback from various colleagues. Let me quote one of the comments by participants that we received via e-mail after the conference:

*Dear Rainer, Rudi, and Peter, and to all the others that helped “in the background”,*

*With this short e-mail I would like to thank you once more for organizing such a spectacular meeting. You managed to put together a programme in which all presentations were of extremely high quality, and the perfection and detail with which everything during the meeting was organized was absolutely exceptional; I can honestly say that I do not recall to have attended a scientific meeting that was better organized than this one, nor a meeting that I found more interesting and exciting than this one. Congratulations to all of you!*

The subjects presented at the conference included almost all hot topics in the field of atomic physics. Lively discussion after each talk, during the coffee breaks, and particularly during the poster sessions promoted intense scientific discourse. Around 180 posters were shown during each of the three poster sessions. Despite the beautiful weather outside and the lack of efficient air-condition inside the poster session area, the poster sessions were cramped with people discussing science.

The high-quality presentations and posters gave an in-depth view of the progress in the field of atomic physics. They allowed participants to assess what the main topics currently are and what the future directions the field are going to be. I will summarize a few directions research is most likely going to focus on.

It became clear from the talks and discussions that coherent manipulation of ultra-cold molecules in their internal and external ground state is going to be one of the major goals for the next few years. The optical frequency comb technology has only started to revolutionize the field. Many more applications and techniques are expected to arise within the next decades. Interactions between ultra-cold heteronuclear fermionic and bosonic molecules have been a widely discussed topic at the conference and will continue to be a hot topic. Precision measurements of fundamental constants and properties of elementary particles have been boosted by the development of new spectroscopy techniques and will have profound influence on the development of theories beyond the standard model of physics.

# Invited talks

Sunday, July 16<sup>th</sup>, 14:00 – 15:45

## Atomic physics–trends and perspectives I

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|               |  |
|---------------|--|
| D. Kleppner   | ICAP 2006 and the evolution of atomic physics          |
| N. F. Ramsey  | Speculating on the future of atomic physics            |
| R. J. Glauber | Some Thoughts on Quantum Amplification and Attenuation |

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Sunday, July 16<sup>th</sup>, 16:15 – 17:25

## Atomic physics–trends and perspectives II

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|                    |  |
|--------------------|--|
| J. Hall            | Stable lasers and atomic physics         |
| C. Cohen–Tannoudji | Ultracold atoms. Trends and perspectives |

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Monday, July 17<sup>th</sup>, 8:30 – 10:15

## Fundamental physics and precision measurements I

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|                |  |
|----------------|--|
| T. W. Hänsch   | Fundamental physics and precision measurements                               |
| V. V. Flambaum | Effects of variation of fundamental constants from Big Bang to atomic clocks |
| H.–J. Kluge    | Precision experiments with stored and cooled highly charged ions             |

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Monday, July 17<sup>th</sup>, 10:45 – 12:30

## Fundamental physics and precision measurements II

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|                |   |
|----------------|---|
| J. Ye          | Precision measurement based on ultracold atoms and cold molecules                                     |
| H. S. Margolis | Trapped ion optical clocks at NPL   |
| W. Ubachs      | Precision spectroscopy of H <sub>2</sub> and a possible variation of $m_p/m_e$ over cosmological time |

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Monday, July 17<sup>th</sup>, 14:00 – 15:45

**Theory**

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|                |   |
|----------------|---|
| M. Ueda        | Symmetry breaking in Bose-Einstein condensates                |
| P. S. Julienne | Simple theoretical models for resonant cold atom interactions |
| V. M. Shabaev  | Quantum electrodynamics of heavy ions and atoms               |

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Monday, July 17<sup>th</sup>, 20:00 – 21:30

**Evening lecture**

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|           |   |
|-----------|---|
| C. Wieman | Education in the 21 <sup>st</sup> century; a scientific approach to science education |
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Tuesday, July 18<sup>th</sup>, 8:30 – 10:15

**Bose Einstein condensates**

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|               |  |
|---------------|--|
| J. Dalibard   | Atomic Bose gases in low dimensions              |
| M. Oberthaler | Bosonic Josephson junction at finite temperature |
| E. Demler     | Interference between fluctuating condensates     |

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Tuesday, July 18<sup>th</sup>, 10:45 – 12:30

**Fermi gases**

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|              |   |
|--------------|---|
| W. Ketterle  | Superfluidity in a gas of fermionic atoms                       |
| K. Sengstock | Fermi-Bose mixtures in three-dimensional optical lattices       |
| S. Giorgini  | Fermi gas in the BCS-BEC crossover: a quantum Monte Carlo study |

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Tuesday, July 18<sup>th</sup>, 14:00 – 15:45

**Hot topics I**

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|               |  |
|---------------|--|
| J. Denschlag  | Repulsively bound atom pairs in an optical lattice   |
| S. Dürr       | A Mott state of molecules  |
| M. Inguscio   | Insulating phases of ultracold bosons in a disordered optical lattice: from a Mott insulator to a Bose-Glass |
| K. Karrai     | Light induced self-cooling of micro-levers   |
| H. P. Büchler | Designing interactions in polar molecules: towards novel quantum phases                                      |

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Wednesday, July 19<sup>th</sup>, 8:30 – 10:15

**Quantum information processing with atoms and ions**

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|                |  |
|----------------|--|
| D. J. Wineland | Trapped atomic ions and quantum information processing |
| C. F. Roos     | Entangled states for precision spectroscopy            |
| M. D. Lukin    | Quantum bits and quantum wires in solid state          |

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Wednesday, July 19<sup>th</sup>, 10:45 – 12:30

**Quantum optics and cavity QED with atoms**

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|                  |   |
|------------------|---|
| G. Remppe        | Cavity QED: A toolbox for achieving full control over massive and light particles |
| H. J. Kimble     | Quantum optics with atomic ensembles and single atoms in cavities                 |
| R. J. Schoelkopf | Circuit QED and the prospects for quantum circuits with polar molecules           |

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Wednesday, July 19<sup>th</sup>, 20:00 – 21:30

**Evening lecture**

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|             |   |
|-------------|---|
| W. Phillips | Time, Einstein, and the coolest stuff in the universe |
|-------------|---|

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Thursday, July 20<sup>th</sup>, 8:30 – 10:15

**Cold molecules**

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|             |  |
|-------------|--|
| J. M. Doyle | Cold polar molecules                               |
| G. Meijer   | Slowing and trapping of polar molecules            |
| D. DeMille  | Production of ultracold polar molecules from atoms |

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Thursday, July 20<sup>th</sup>, 10:45 – 12:30

**Chip traps for atoms, ions and molecules**

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|                 |   |
|-----------------|---|
| J. Reichel      | Atom chip applications  |
| J. H. Thywissen | Atom chips for neutral fermions                                 |
| R. E. Slusher   | Scalable ion traps with monolithically integrated CMOS controls |

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Thursday, July 20<sup>th</sup>, 14:00 – 15:45

**Hot topics II**

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|                 |   |
|-----------------|---|
| H.C. Nägerl     | Experimental evidence for Efimov quantum states                                 |
| C. I. Westbrook | Producing correlated atoms from degenerate quantum gases                        |
| E. S. Polzik    | Quantum teleportation between light and matter                                  |
| E. A. Hinds     | Probing the electron EDM with cold molecules                                    |
| G. Gabrielse    | New measurement of the electron magnetic moment and the fine structure constant |

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Friday, July 21<sup>st</sup>, 8:30 – 10:15

**Attosecond physics with atoms**

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|                |  |
|----------------|--|
| A. L’Huillier  | Atomic physics with attosecond pulses                            |
| R. Kienberger  | Single attosecond pulses and first applications                  |
| J. P. Marangos | Probing attosecond dynamics by chirp encoded electron collisions |

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Friday, July 21<sup>st</sup>, 10:45 – 12:30

**Atoms in optical lattices**

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|               |  |
|---------------|--|
| T. Esslinger  | A lab in a trap: Fermions, molecules and Bose-Fermi mixtures in an optical lattice |
| I. Bloch      | Strongly correlated atoms in optical lattices                                      |
| M. Lewenstein | Travelling to exotic places with ultracold atomic gases                            |

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