Q 25: Matter Wave Optics

Time: Wednesday 10:30–13:00 Location: BAR Schön

Q 25.1 Wed 10:30 BAR Schön

Quantum test of the equivalence principle with dual species atom interferometry — •Daniel Tiarks, Jonas Hartwig, Dennis Schlippert, Ulrich Velte, Maic Zaiser, Vyacheslav Lebedev, Ernst Rasel, and Wolfgang Ertmer — Institut für Quantenoptik, Hannover

The CAPRICE experiment is aiming for a test of the equivalence principle using atom interferometry with two atomic species. For this test we trap and cool rubidium and potassium atoms in a two-stage loading scheme using a 2D/3D MOT. Both atomic ensembles are then dropped for a simultaneous differential measurement of the Earth's gravitation g. This setup allows us to make systematic studies concerning the comparison of interferometry with bosonic and fermionic matter and the metrological comparison of two different gravimeters at the same place and in the same experimental environment. A very compact diode laser system is used for cooling and coherently manipulating the atomic clouds. We will show a characterisation of the present detection system as well as first studies of gravitational measurements using ^{87}Rb.

To guarantee well defined starting conditions the two species will be trapped in an optical dipole trap formed by a Thulium doped fiber laser with 50 W output power at a wavelength of 1960 nm. The special properties of this optical dipole trap allow for fast and efficient cooling.

Q 25.2 Wed 10:45 BAR Schön

Atom Interferometry in a mobile high-precision setup to measure local gravity — •Matthias Hauth, Malte Schmidt, Alexander Senger, Vladimir Schkolnik, Christian Freier, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin

GAIN (Gravimetric Atom Interferometer) is a mobile gravimeter, based on interfering ensembles of laser cooled ^{87}Rb atoms in an atomic fountain configuration. The high-precision interferometer is designed to reach an accuracy of a few parts in 10^{10} for the measurement of local gravity, g.

We give an introduction into the working principle of our mobile atom interferometer based on a Raman-sequence driving the hyperfine transition of the ^{87}Rb ground state and report on our first move to another laboratory. Furthermore we present first gravity-measurements showing earth tides, the current status and steps planned for the future.

Q 25.3 Wed 11:00 BAR Schön

Matter wave interferometry: Molecular mass, complexity, dynamics and structure — •Sandra Eibenberger[1], Stefan Gerlich[1], Jens Tüxen[2], Stefan Nimmrichter[1], Marcel Mayor[2], and Markus Arndt[1] — [1]University of Vienna, Quantum Nanophysics, Austria — [2]University of Basel, Department of Chemistry, Switzerland

Kapitza-Dirac-Talbot-Lau interferometry is a versatile tool for studying the wave nature of massive and complex molecules.

De Broglie coherence is to first order only associated with the center-of-mass motion. In the presence of external perturbations, however, internal molecular properties, such as electric susceptibilities, polarizabilities or dipole moments become accessible without introducing genuine decoherence.

Recent experimental data from high-contrast interference measurements with massive and complex molecules are presented. The influence of molecular dynamics on de Broglie coherence and the distinction of structural isomers via quantum metrology are shown.

References:

M. Gring et al. Phys. Rev. A 81, 031604 (2010)
J. Tüxen et al. Chem. Commun. 46, 4145-4147 (2010)
S. Gerlich et al. Angewandte Chemie Int. Ed. 47, 6195-6198 (2008)
K. Hornberger et al. NJP 11, 043032 (2008)

Q 25.4 Wed 11:15 BAR Schön

Chip-based Bragg interferometry with Bose-Einstein condensates in microgravity — •Markus Krutzik[1], Achim Peters[1], and the QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Physik, HU Berlin — [2]Institut für Quantenoptik, LU Hannover — [3]Institut für Laserphysik, Uni Hamburg — [4]ZARM, Uni Bremen — [5]Institut für Quantenphysik, Uni Ulm — [6]MPQ, München — [7]Institut für angewandte Physik, TU Darmstadt — [8]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [9]FBH, Berlin

The successful observation of Bose-Einstein-Condensation in microgravity was an important result towards operating dilute quantum gas experiments under extreme conditions (van Zoest et al., Science **328** 2010). In this talk we report on atom-optical experiments with a BEC produced in this apparatus, performed on ground as well as in free fall. The coherent manipulation of the ensemble is realized with stimulated Bragg diffraction as a splitting and recombination process. Using a simple interferometer composed of two Bragg pulses we investigated the phase-coherence of the ensemble by oberserving the spatial fringe pattern with free evolution times up to 500ms. In the near future we intend to realize multiphoton Mach-Zehnder topologies to achieve extremely large distances between the diffracted wave packets and even longer timescales within the sequence.

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Q 25.5 Wed 11:30 BAR Schön

Molecule Interferometer at Southampton — •Carola Szewc, Paul Venn, and Hendrik Ulbricht — University of Southampton, School of Physics and Astronomy, Highfield, SO17 1BJ, Southampton, United Kingdom

De Broglie interference experiments with large molecules are of interest to address fundamental physics related to limitations of quantum physics, but also for applications like molecule metrology as demonstrated by the Vienna group. We will report on our progress of setting up a vertical molecule Talbot-Lau interferometer at Southampton. This three material grating interferometer will enable interference and metrology experiments of particles of up to 10,000 amu (atomic mass units), which is an important intermediate step towards very massive particle interferences to attack the fundamental questions. Furthermore, that mass range is important for metrology experiments with organic molecules. While some analytic methods basing on molecule interference have been demonstrated - as the measurement of molecule's polarizability, dipole moments and molecular quantum interference lithography as a new bottom-up nanofabrication technique - other proposals on molecule sorting and single photon recoil spectroscopy are still waiting for experimental realization. Studies by our molecule interferometer include the mapping of the molecule distribution to extract the full information about the molecular quantum state by Wigner function tomography as well as the study of van der Waals/Casimir-Polder interactions between molecules and diffraction gratings.

Q 25.6 Wed 11:45 BAR Schön

Trapped atomic gravimeter for near-field force measurements — •Gunnar Tackmann, Quentin Beaufils, Bruno Pelle, Sophie Pélisson, Xiaolong Wang, Marie-Christine Angonin, Peter Wolf, and Franck Pereira Dos Santos — LNE-SYRTE, Observatoire de Paris, CNRS, UPMC, 61 avenue de l'Observatoire, 75014 Paris, France

The realization of matter-wave interferometry on neutral atoms in a vertical 1D lattice coupling the system's eigenstates, namely the Wannier-Stark states, permits high precision measurements of the energy difference between the lattice wells. In addition to the absolute determination of the gravitational acceleration, this will allow the mapping of the Casimir-Polder potential between the neutral atoms and a macroscopic surface as well as to push the limits on possible derivations from Newtonian gravitation on short distances when performed in the vicinity of the retro-reflective lattice mirror's surface.

In the experiment Forca-G, such an interferometer is realized with ^{87}Rb atoms in a 532 nm lattice. In this talk, we present the current performance of the interferometer far from the mirror surface. Featuring long coherence times in the order of seconds, these measurements are currently limited by the trap lifetime.

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Framework Programme for Research of the European Commission, under FET-Open grant number: 250072. We also gratefully acknowledge support by Ville de Paris ("Emergence(s)" program) and IFRAF.

Q 25.7 Wed 12:00 BAR Schön

A dual species matter-wave interferometer in microgravity — •Jan Rudolph[1], Ernst Maria Rasel[1], and the QUANTUS Team[2,3,4,5,6,7,8,9] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Universität Bremen — [3]Institut für Physik, HU Berlin — [4]Institut für Laser-Physik, Universität Hamburg — [5]Institut für Quantenphysik, Universität Ulm — [6]Institut für angewandte Physik, TU Darmstadt — [7]MUARC, University of Birmingham — [8]FBH, Berlin — [9]MPQ, Garching

The QUANTUS-II apparatus is a matter-wave interferometer that is designed to operate in free fall with two atomic species simultaneously. This will enable us to perform differential measurements of ^{87}Rb and ^{40}K atoms and thus provide a test of the weak equivalence principle in the quantum domain. The experiment will be carried out in the microgravity environment of the drop tower in Bremen. Here our predecessor project QUANTUS has already demonstrated the feasibility of experiments with ultra-cold gases in free fall, realizing a Bose-Einstein condensate and subsequently observing its free evolution for up to one second. We aim to realise an apparatus that is even more compact, operates with a higher number of atoms, uses a more sophisticated atom chip and allows for twice the amount of time in microgravity. In this way we will take advantage of long free evolution times which are inaccessible for ground based devices.
The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM1131.

Q 25.8 Wed 12:15 BAR Schön

Simple description of atom interferometry with Bose-Einstein condensates — •Endre Kajari[1,2], Stefan Arnold[2], Daniela Moll[2], Wolfgang P. Schleich[2], and the QUANTUS Team[3,4,5,6,7,8,9,10] — [1]Theoretische Physik, Universität des Saarlandes — [2]Institut für Quantenphysik, Universität Ulm — [3]Institut für Quantenoptik, LU Hannover — [4]ZARM, Universität Bremen — [5]Institut für Physik, HU Berlin — [6]Institut für Laser-Physik, Universität Hamburg — [7]Institut für angewandte Physik, TU Darmstadt — [8]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [9]FBH, Berlin — [10]MPQ, Garching

In this talk we present the theoretical formalism used in the analysis of the long-time evolution of Bose-Einstein condensates in microgravity [1]. Starting from a natural generalization of the scaling approach [2] which addresses time-dependent rotating traps, we identify the range of application of this description, introduce a Hamilton formalism for the new dynamical variables, and point out the connection to the constants of motion of the Gross-Pitaevskii equation. Since this approach provides us with an accurate phase evolution of the macroscopic wave function as well, it represents a valuable tool for the description of atom interferometry with Bose-Einstein condensates.
The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50 WM 1136.
[1] T. van Zoest et al., Science **328**, 1540 (2010).
[2] Y. Castin and R. Dum, Phys. Rev. Lett. **77**, 5315 (1996).

Q 25.9 Wed 12:30 BAR Schön

Matter wave optics with Bose-Einstein condensates in microgravity — •Hauke Müntinga[1], Claus Lämmerzahl[1], and the QUANTUS Team[2,3,4,5,6,7,8,9,10] — [1]ZARM, Universität Bremen — [2]Institut für Quantenoptik, LU Hannover — [3]Institut für Physik, HU Berlin — [4]Institut für Laser-Physik, Universität Hamburg — [5]Institut für Quantenphysik, Universität Ulm — [6]Institut für angewandte Physik, TU Darmstadt — [7]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [8]FBH, Berlin — [9]MPQ, Garching — [10]Laboratoire Kastler Brossel, ENS, Paris

In 2007 the first Bose-Einstein condensate in microgravity was realized by the QUANTUS collaboration in the ZARM drop tower in Bremen. In over 200 drops from a height of 110 m, our setup has proven the feasibility of operating delicate quantum optical experiments in demanding environments and allowed us to study the physics of ultra-cold quantum gases in previously inaccessible parameter regimes.

After examining the free evolution of the condensate for up to 1 s [1], we have now integrated a matter wave interferometer based on Bragg diffraction into out apparatus. In our talk we will describe the current setup and give an abstract of recent measurements addressing e.g. the phase evolution of the condensate on macroscopic time scales.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50 WM 1135.

[1] T. van Zoest et al., Science **328**, 1540 (2010).

Q 25.10 Wed 12:45 BAR Schön

Delta kick cooling: a method for fast adiabatic decompression and its applications to atom interferometry — •Andre Wenzlawski[1], Klaus Sengstock[1], and the QUANTUS team[1,2,3,4,5,6,7,8,9] — [1]Institut für Laser-Physik, Universität Hamburg — [2]Institut für Quantenoptik, Universität Hannover — [3]Institut für Physik, HU Berlin — [4]ZARM, Universität Bremen — [5]Institut für angewandte Physik, TU Darmstadt — [6]Institut für Quantenphysik, Universität Ulm — [7]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [8]FBH, Berlin — [9]MPQ, Garching

The first realization of a Bose-Einstein condensate in microgravity in 2007 paved the way for the observation of freely evolving ultra cold quantum gases on a much longer timescale than possible in any ground based experiment. We were able to observe a freely expanding BEC for up to 1 second [1] but for longer evolution times the atomic cloud got too thin to be detected efficiently.
To further increase the observation time the concept of delta kick cooling has been implemented in the experimental apparatus. This technique makes use of a magnetic lens and as a result the expansion of the BEC can be slowed down. In this talk I will report on the status of this project and on its applications to our goal to do atom interferometry in space.
The QUANTUS Project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM1133.
[1] T. van Zoest et al., Science **328**, 1540 (2010).