Q 68: Materiewellenoptik

Time: Friday 14:00–16:00 Location: V53.01

Q 68.1 Fri 14:00 V53.01

QUANTUS I - Matter wave interferometry in the bremen drop tower — •Hauke Müntinga[1], Sven Herrmann[1], Claus Lämmerzahl[1], and the QUANTUS TEAM[1,2,3,4,5,6,7,8,9] — [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]MUARC, University of Birmingham — [8]FBH, Berlin — [9]DLR Institut für Raumfahrtsysteme, Bremen

In 2007 the first Bose-Einstein condensate in microgravity was realized by the QUANTUS collaboration in the ZARM drop tower in Bremen.

In nearly 350 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 ultracold 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 our apparatus. In our talk we will describe the current setup and give an overview of recent experimental campaigns addressing the extension of the interrogation time of a Mach-Zehnder type interferometer to the realm of seconds.

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.

Q 68.2 Fri 14:15 V53.01

MAIUS - a rocket-borne test of an atom interferometer with a chip-based atom laser — •Stephan Tobias Seidel, Ernst Maria Rasel, and The QUANTUS TEAM — Institut für Quantenoptik, LU Hannover

The test of the Einstein's equivalence principle with degenerate quantum matter is one the strategies to explore the frontier between quantum mechanics and gravity. A precise test for this equivalence is the comparisons of the free fall of ultra-cold clouds of different atomic species and its readout using atom interferometry. In order to increase the precision of such an interferometer the space-time-area enclosed in it has to be increased. This can be achieved by performing the experiments in a weightless environment that allows longer interrogation times.

As a next step towards the transfer of such a system to space, either on-board the international space station or as a dedicated satellite mission, a rocket-based atom interferometer is currently being build. With the launch of the rocket mission in November 2013 we plan to demonstrate and test such an apparatus in space for the first time. Its success would mark a major advancement towards a precise measurement of the equivalence principle with a space-borne atom interferometer.

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 68.3 Fri 14:30 V53.01

Interferometry with δ-kick cooled atoms — •André 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 observation of a freely expanding Bose-Einstein Condensate in microgravity [1] paved the way for realizing atom interferometers on unprecedented time scales.

To even further extend the available interrogation time for the interferometer the concept of delta kick cooling has been implemented in the experimental apparatus. By using pulsed magnetic fields we can manipulate the momentum distribution of the atoms which allows for the preparation of the atoms in a very narrow momentum distribution. With this method we are also able to use non velocity selected thermal atoms in an atom interferometer. In this talk I will report on recent results obtained with delta-kick cooled atoms.

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).

Q 68.4 Fri 14:45 V53.01

Micro-integrated, narrow linewidth master-oscillator-power-amplifier laser system with 3 W output power — •Max Schiemangk[1], Achim Peters[1,9], 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

We present an all-diode laser based, hybrid integrated laser module, that will be used within QUANTUS II at the Drop Tower Bremen. The 10 × 50 mm^2 module is based on a master oscillator power amplifier (MOPA) concept. A distributed feedback (DFB) laser diode is used as master oscillator (MO), that provides narrow linewidth emission. The output of the MO is collimated by micro-lenses, passed through a micro-optical isolator to supress feedback, and injected into a power amplifier (PA) chip. The PA consists of a ridge-waveguide pre-amplifier section, that serves as a mode filter, and a tapered section, that boosts the output power to about 3 W while preserving the spectral properties. The module's FWHM linewidth corresponds to approx. 1 MHz (10 μs time scale) and the intrinsic linewidth derived from the white noise floor of the frequency noise spectrum is below 200 kHz.

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 numbers DLR 50WM1131-1137.

Q 68.5 Fri 15:00 V53.01

Twin Matter Waves for Interferometry Beyond the Classical Limit — •Bernd Lücke[1], Manuel Scherer[1], Jens Kruse[1], Luca Pezze[2], Frank Deuretzbacher[3], Philipp Hyllus[3], Oliver Topic[1], Jan Peise[1], Wolfgang Ertmer[1], Jan Arlt[4], Luis Santos[3], Augusto Smerzi[2], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany — [2]Istituto Nazionale di Ottica (INO), Consiglio Nazionale delle Ricerche (CNR), and European Laboratory for Non-Linear Spectroscopy (LENS), 50125 Firenze, Italy — [3]Institut für Theoretische Physik, Leibniz Universität Hannover, 30167 Hannover, Germany — [4]Center for Quantum Optics (QUANTOP), Institut for Fysik og Astronomi, Aarhus Universitet, 8000 Århus C, Denmark

Interferometers with atomic ensembles are an integral part of modern precision metrology. However, these interferometers are fundamentally restricted by the shot noise limit, which can only be overcome by creating quantum entanglement among the atoms. We employ spin dynamics in Bose-Einstein condensates to create large ensembles of up to 10000 pair-correlated atoms and thus achieve this goal. The fluctuation of the population difference in the two output states is -6.9 dB below shot noise and is mainly limited by the detection noise of 30 atoms. Moreover we show that this twin state has an interferometric sensitivity -1.61 dB beyond the shot noise limit. Our proof-of-principle results point the way toward a new generation of atom interferometers.

Q 68.6 Fri 15:15 V53.01

Matter-Wave Interferometry with Ions — •Georg Schütz[1], Alexander Rembold[1], Andreas Pooch[1], Franz Hasselbach[1], Ing-Shouh Hwang[2], and Alexander Stibor[1] — [1]Physikalisches Institut Tübingen, Auf der Morgenstelle 15, 72076 Tübingen — [2]Institute of Physics, Academia Sinica, Academia Rd., 11529 Nankang, Taipei

The big success of matter-wave experiments with neutral particles and electrons within the last 20 years encourage the development of a new type of interferometer for ions. We report on the present status in the construction of the first stable ion-interferometer.

Compared to neutral atomic or molecular interferometers, the additional parameter charge opens the door for fundamental quantum-mechanical experiments, such as the magnetic and electric Aharonov-

Bohm effect.

In the development of this device the long term experience in the manipulation of electron-waves are utilized on ions. In our experimental approach a coherent matter-wave of charged particles gets separated and recombined by an extremely thin, charged biprism wire, resulting in an interference pattern in the detection plane. A novel technique allows for a stable ion emission from a single atom apex of a pyramidal shaped metal tip. The resulting charged matter-waves are highly monochromatic and coherent. Since ions or even charged molecules in this kind of interferometer are significantly heavier and slower compared to electrons, highly sensitive, compact sensors for rotation and acceleration come into reach of current technical possibilities.

Q 68.7 Fri 15:30 V53.01

High resolution Sagnac atom interferometer — •Peter Berg, Christian Schubert, Gunnar Tackmann, Sven Abend, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

Within the gyroscope experiment CASI (Cold Atom Sagnac Interferometer), a compact dual cold-atom interferometer for high resolution measurement of slow rotations is realised. Employing three separate beam-splitter light fields an area of 19 mm^2 is enclosed. We discuss the high demands of the relative beam-splitter light field alignment at the position of the atoms, which excludes standard optical alignment techniques. These are met by an alignment technique utilising the interferometer itself. The resulting gyroscope resolution of $5.3\ 10^{-7}\mathrm{rad/s}/\sqrt{\mathrm{Hz}}$ is mainly limited by environmental vibrations. This work is supported by the DFG, the cluster of excellence QUEST, and IQS.

Q 68.8 Fri 15:45 V53.01

An ionizing time-domain matter-wave interferometer — •Nadine Dörre[1], Philipp Haslinger[1], Philipp Geyer[1], Jonas Rodewald[1], Stefan Nimmrichter[1], Klaus Hornberger[2], and Markus Arndt[1] — [1]University of Vienna, Vienna Center of Quantum Science and Technology, Vienna , Austria — [2]University of Duisburg-Essen, Duisburg, Germany

We present the concept and a recent setup of an all-optical matter-wave interferometer for clusters and complex molecules that combines absorptive ionization gratings with the advantages of interferometry in the time domain. In this setup, we use a sequence of three equally timed UV lasers pulses reflected from a single mirror to form standing wave gratings that diffract the particles in the time domain. These gratings can act as absorptive masks for matter waves, as soon as the absorption of a single photon leads to ionization of each particle in the vicinity of anti-nodes of the standing wave. In contrast to material grating setups, this experiment operates in a pulsed mode, which reduces the influence of the longitudinal particle motion. This turns the interferometer into a universal tool which, on the one hand, will allow us to explore the quantum wave nature of very massive particles. In combination with deflectometry and spectroscopy, on the other hand, it offers the possibility to determine properties of organic and metal clusters with high precision, among them polarizabilities, electric and magnetic moments, absorption and ionization cross sections.