Q 9: Matter wave optics II

Time: Monday 14:00–15:45 Location: DO26 208

Q 9.1 Mon 14:00 DO26 208

High resolution rotation sensing with cold atoms — •Sven Abend, Peter Berg, Gunnar Tackmann, Christian Schubert, Wolfgang Ertmer, and Ernst Maria Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland

We present a novel geometry utilizing cold-atom interferometry for inertial sensitive measurements by symmetrizing a Mach-Zehnder type geometry for Raman type beam splitters. Using this technique we demonstrated a gyroscope with flat parabolic atomic trajectories in which an area of 0.41 cm^2 is realized on a baseline of 14 cm. The sensor showed a sensitivity to rotations of 120 $nrads^{-1}Hz^{-1/2}$ with a technical noise floor of 60 $nrads^{-1}Hz^{-1/2}$ and a stability of 26 $nrads^{-1}$ after 100 s. This work is supported by the DFG, the cluster of excellence QUEST, and IQS.

Q 9.2 Mon 14:15 DO26 208

Multidimensional nonlinear modes in BEC condensates with strongly non-uniform repulsive nonlinearity — •Rodislav Driben[1], Yaroslav Kartashov[2], Boris Malomed[3], Torsten Meier[1], and LLuis Torner[2] — [1]Department of Physics & CeOPP, University of Paderborn — [2]ICFO-Institut de Ciencies Fotoniques, and Universitat Politecnica de Catalunya, Mediterranean Technology Park, E-08860 Castelldefels (Barcelona) — [3]Department of Physical Electronics, School of Electrical Engineering, Faculty of Engineering, Tel Aviv University, Tel Aviv 69978, Israel

We demonstrate stable families of 3-dimensional solitons and toroidal-shaped votices in BEC condensates with self-trapping induced by a spatially growing strength of the repulsive nonlinearity [1]. The application of a moderate torque to the vortex torus initiates its persistent precession mode, with the torus axle moving along a conical surface. Strong torque nearly destroys the vortex; nonetheless, it restores itself, with the axle oriented according to the vectorial addition of angular momenta. Interaction between several 3D condensates is further considered in this setting, demonstrating interesting dynamical effects. The analysis is performed by analytical methods in combination with comprehensive numerical simulations.

[1] R.Driben, Y.Kartashov, B. A. Malomed, T. Meier, and L.Torner, "Soliton gyroscopes in media with spatially growing repulsive nonlinearity" Phys. Rev. Letters in Press,(2013).

Q 9.3 Mon 14:30 DO26 208

Laser gratings in matter wave interferometry — •Kai Walter and Klaus Hornberger — Fakultät für Physik, Universität Duisburg-Essen

A viable way of exploring the limit of quantum physics is to probe matter-wave interference with large particles [1]. In such experiments a standing wave laser grating is often used, rather than a material mask, because of its perfect periodicity and high transmission. For this purpose it is important to account for the different types of interaction between a particle and the laser field. Large particles are usually highly polarizable and thus experience a strong phase modulation due to the laser-dipole interaction. On the other hand, the particles can also absorb laser photons, which is an incoherent process. Moreover, a metastable excited state with higher polarizability and larger absorbtion cross section can also play a role. The interplay of these effects, which can be described by a Lindblad type master equation, will be discussed by means of a concrete experimental setup.

[1] M. Arndt et al., Nature Physics 3, 711 - 715 (2007)

Q 9.4 Mon 14:45 DO26 208

A miniaturized, high flux BEC source for precision interferometry — •Jan Rudolph[1], Ernst Maria Rasel[1], and The QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Quantenoptik, Leibniz Universität 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

Atom chips have proven to be excellent sources for the fast production of ultra-cold gases due to their outstanding performance in evaporative cooling. However, the total number of atoms has previously been limited by the small volume of their magnetic traps. To overcome this restriction, we have developed a novel loading scheme that allows us to produce Bose-Einstein condensates of 4x10^5 ^{87}Rb atoms every 1.6 seconds. Ensembles of 1x10^5 atoms can be produced with 1Hz repetition rate. The apparatus is designed to be operated in microgravity at the drop tower in Bremen, where even higher numbers of atoms can be achieved in the absence of any gravitational sag.

Using the drop tower's catapult mode, our setup will perform atom interferometry during nine seconds in free fall. Thus, the fast loading scheme allows for interferometer sequences of up to seven seconds – interrogation times which are inaccessible for ground based devices.

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Q 9.5 Mon 15:00 DO26 208

Optomechanical Interface for Probing Matter-Wave Coherence — •Hendrik Ulbricht[1], André Xuereb[2,3], and Mauro Paternostro[2] — [1]Physics and Astronomy, University of Southampton, Southampton, SO17 1BJ, UK — [2]Centre for Theoretical Atomic, Molecular and Optical Physics, School of Mathematics and Physics, Queen's University Belfast, BT7 1NN, UK — [3]Department of Physics, University of Malta, Msida MSD2080, Malta

We combine matter-wave interferometry and cavity optomechanics to propose a coherent matter-light interface based on mechanical motion at the quantum level. We demonstrate a mechanism that is able to transfer non-classical features imprinted on the state of a matter-wave system to an optomechanical device, transducing them into distinctive interference fringes. This provides a reliable tool for the inference of quantum coherence in the particle beam. Moreover, we discuss how our system allows for intriguing perspectives, paving the way to the construction of a device for the encoding of quantum information in matter-wave systems. Our proposal, which highlights previously unforeseen possibilities for the synergistic exploitation of these two experimental platforms, is explicitly based on existing technology, available and widely used in current cutting-edge experiments.

Q 9.6 Mon 15:15 DO26 208

Phase-space evolution of interferences in atom interferometers — •Enno Giese, Wolfgang Zeller, Stephan Kleinert, Vincenzo Tamma, Albert Roura, and Wolfgang P. Schleich — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

The appearance of a phase shift due to linear gravity and gravity gradients in atom interferometers is well-known and can be explained in numerous ways with different interpretations. A Wigner phase-space representation allows an intuitive understanding of the contrast in the exit ports, in addition to an explicit expression for the interferometer phase.

The final state of a Kasevich-Chu interferometer in Wigner phase space has a Schrödinger-cat-like form and consists of three contributions: one arising from the upper, one from the lower interferometer path, and one describing the interference. We present quantum Liouville-type of equations of motion for these three contributions. We focus in particular on the beam splitters and mirrors and investigate their action on the trajectories of the upper and lower path in phase space.

In addition to that, we demonstrate that the interference term is created by the momentum shifts of the beam splitter pulses. The interference quantum Liouville equation leads to a trajectory between the upper and lower path. Furthermore, we show how an inhomogeneity in the equation of motion imprints the interferometer phase on the interference term.

Q 9.7 Mon 15:30 DO26 208

Double Bragg Diffraction in a Matter Wave Interferometer with BECs — •Hauke Müntinga[1], Claus Lämmerzahl[1], and the QUANTUS Team[1,2,3,4,5,6] — [1]ZARM, U Bremen — [2]LU Hannover — [3]HU Berlin — [4]U Hamburg — [5]U Ulm — [6]TU Darmstadt

Matter wave interferometers based on Bragg diffraction have recently gained momentum in comparison to Raman diffraction due to their ability to directly populate higher diffraction orders with a single laser pulse to scale sensitivity. In microgravity, the system becomes symmetric, and Double Diffraction occurs [1]: The atoms are at rest and interact with both beam pairs, thus three momentum states are coupled. This suppresses systematic effects from laser phase noise and makes Double Diffraction an interesting tool to investigate for precision measurements.

In this talk, we report on first ground based experiments carried out in the QUANTUS-I apparatus [2]: The laser beams are aligned perpendicular to gravity, and with a delta-kick cooled BEC a Mach-Zehnder type interferometer is created. A small gravitational acceleration is introduced resulting in a phase shift in the interferometer signal. We demonstrate scalability of the system by observing interference fringes with first order, sequential first order, and second order Bragg pulses.
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 50WM1131-1137.

[1] Giese et al., PRA 88, 053608

[2] Müntinga, Ahlers, Krutzik, Wenzlawski et al., PRL 110, 093602