Q 2: Matter wave optics I

Time: Monday 10:30–12:15 Location: DO26 208

Q 2.1 Mon 10:30 DO26 208

Matter-wave interferometry of a free-falling nanoparticle — •James Bateman[1], Muddassar Rashid[1], David Hempston[1], Jamie Vovrosh[1], Stefan Nimmrichter[2], Klaus Hornberger[2], and Hendrik Ulbricht[1] — [1]School of Physics and Astronomy, University of Southampton, UK — [2]Fakultät für Physik, Universität Duisburg-Essen, Duisburg, Germany

We describe the theory, design choices, and experimental progress of a near-field matter-wave interferometer for 10^6 amu nanoparticles emanating from a point-like source and subject to a phase-grating. Using a phase-space description, and accounting for all relevant decoherence mechanisms, we find an experimentally feasible scenario in which to expect high-contrast fringes. Experimental components include: a UHV-compatible high-purity nanoparticle source; feedback stabilisation to strongly localise the particle; 355nm micro-Joule nano-second pulses; sub-100nm position resolution; interferometric stability over the 50cm free-fall distance. Observation of the predicted fringes will begin to constrain stochastic modifications to the Schrödinger equation. This simple, low-power geometry is well suited to future space-based experiments in which we anticipate accessing considerably higher masses.

Q 2.2 Mon 10:45 DO26 208

Matter-wave interferometry in non-inertial frames — •Stephan Kleinert[1], Albert Roura[1], Wolfgang P. Schleich[1], and the QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Quantenphysik, Universität Ulm, D-89081 Ulm, Germany — [2]Institut für Quantenoptik, LU Hannover — [3]ZARM, Universität Bremen — [4]Institut für Physik, HU Berlin — [5]Institut für Laser-Physik, Universität Hamburg — [6]Institut für angewandte Physik, TU Darmstadt — [7]MUARC, University of Birmingham, UK — [8]FBH, Berlin — [9]MPQ, Garching

The enormous progress in the coherent manipulation of atoms has enabled the use of atom interferometers for high-precision measurements [1,2]. They play a central role in the implementation of clocks, inertial sensors and gravimeters.

Our talk focuses on matter-wave interferometers embedded in non-inertial reference frames necessary for the description of state-of-the-art space missions. We show that effects due to non-inertial reference frames can be easily interpreted when the general coordinate transformation is decomposed into elementary ones. In particular, the transformation into a rotating frame modifies the ordinary Sagnac terms.

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 50WM1136.

[1] C. J. Bordé, Physics Letters A 140, 10 (1989).
[2] M. Kasevich and S. Chu, Phys. Rev. Lett. 67, 181 (1991).

Q 2.3 Mon 11:00 DO26 208

Correction of dephasing oscillations in matter wave interferometry — •Alexander Rembold, Georg Schütz, Andreas Pooch, Andreas Günther, and Alexander Stibor — Physikalisches Institut, Universität Tübingen, 72076 Tübingen, Deutschland

Vibrations, electromagnetic oscillations and temperature drifts are among the main reasons for dephasing in matter wave interferometry. Sophisticated interferometry experiments often require integration times of several minutes. Here we present a scheme to suppress the influence of such dephasing mechanisms - especially in the low frequency regime - by analyzing temporal and spatial particle correlations available in modern detectors. Such correlations can reveal interference properties which would otherwise be washed out due to dephasing by external oscillating signals. The method is shown experimentally in a biprism electron interferometer [1] where artificially a perturbing oscillation is introduced by a periodically varying magnetic field. We provide a full theoretical description of the particle correlations where the perturbing frequency and amplitude can be revealed from the disturbed interferogram. The original spatial fringe pattern without the perturbation can thereby be restored. The technique can be applied to lower the general noise requirements in matter wave interferometers. It allows for the optimization of electromagnetic shielding and decreases the efforts for vibrational or temperature stabilization.

[1] F. Hasselbach and U. Maier, 1999 Quantum Coherence and Decoherence, Proc. ISQM, Tokyo 98, ed. by Y.A. Ono and K. Fujikawa (Amsterdam: Elsevier), 299 (1999)

Q 2.4 Mon 11:15 DO26 208

Influence of the orientation state in matter-wave interferometry with large molecules — •Benjamin A. Stickler, Stefan Nimmrichter, and Klaus Hornberger — Faculty of Physics, University of Duisburg-Essen, Lotharstrasse 1 - 21, Duisburg

Near field matter-wave interferometry with optical phase gratings has been achieved with complex molecules of masses up to 10^4 amu [1]. Experiments with even larger and heavier molecules will be realized in the near future. Their theoretical description requires one to go beyond the point particle approximation and to incorporate orientation-dependent molecule-grating interactions. Starting from the simplified scenario of a linear rigid rotor rotating around a single fixed axis, we develop a quantum scattering theory description of the interference of arbitrarily shaped molecules. Here, we focus on optical phase grating interactions. The prospects and limitations of this approach, as well as experimental accessible signatures of the orientation state, will be discussed.

[1] K. Hornberger, S. Gerlich, P. Haslinger, S. Nimmrichter, and M. Arndt; Colloquium: Quantum interference of clusters and molecules, Rev. Mod. Phys 84, 157 (2012).

Q 2.5 Mon 11:30 DO26 208

Comparison between pure and mixed states in single-shot atom interferometry — •Albert Roura, Wolfgang Zeller, Wolfgang P. Schleich, and the QUANTUS Team — Institut für Quantenphysik, Universität Ulm

Long-time atom interferometry in the range of 5 to 10 s would enable inertial measurements with unprecedented precision (whose sensitivity often grows quadratically with time), such as tests of the weak equivalence principle at the 10^{-15} level. Recent experimental efforts to achieve longer interferometer times have followed two alternative approaches: employing the pure state of a BEC [1] or the mixed thermal state for cold (but non-condensed) atoms [2]. We will introduce first a simple formalism for describing the density profile in open atom interferometers, where the interfering wave packets at the exit ports do not perfectly overlap in position or momentum due to asymmetric pulse timing, rotations or gravity gradients. Next, a convenient extension to mixed states which allows an intuitive comparison with the case of pure states will be presented. It is then straightforward to discuss the limitations of the point-source-interferometry approximation employed to describe recent experiments [2], and to provide an accurate description for the regime beyond its domain of applicability.

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 50WM1136.

[1] H. Müntinga *et al.*, Phys. Rev. Lett. **110**, 093602 (2013)
[2] S. M. Dickerson *et al.*, Phys. Rev. Lett. **111**, 083001 (2013)

Q 2.6 Mon 11:45 DO26 208

A tungsten tip based electron source triggered by laser pulses in the near-ultraviolet — •Dominik Ehberger, Jakob Hammer, and Peter Hommelhoff — Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 1, 91058 Erlangen

Field emission tips as electron sources of nanometric size are known for their extraordinary spatial coherence properties in DC-field emission. By focusing laser pulses on the apex of the tip, electron emission is induced in a temporally well controlled manner.

Here, we will present a fiber based setup for laser-triggered electron emission from ultrasharp tungsten tips. Near-ultraviolet pulses with a mean photon energy of 3.14 eV are generated by frequency doubling of femtosecond Ti:sapphire pulses in bismuth triborate (BiBO). These are coupled to an optical fiber for laser pulse delivery and focused with a gradient-index lens onto a tungsten tip. We will report on our investigations concerning the laser-triggered emission process, which shows a clear signature of a one-photon process. Further emphasis is on the study of the coherence properties of the emitted electrons. From the analysis of electron interference patterns, obtained with an electrostatic biprism made of carbon nanotubes, the figure of merit for spatial coherence, the virtual source radius r_v, is deduced. We find

$r_\mathrm{v} \leq 7\,\mathrm{nm}$ in laser-triggered electron emission for the source presented here.

We will discuss prospects and current limitations of our setup regarding its use as a compact, flexible electron source for various experiments.

Q 2.7 Mon 12:00 DO26 208

An atom-chip based atomic gravimeter — •Holger Ahlers[1], Ernst Maria Rasel[1], and The QUANTUS-TEAM[2,3,4,5,6] — [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

Some of the main limitations of today's atomic gravimeters are set by systematics involving the expansion of the atomic sample during the atom interferometer sequence.

Atom chips provide a promising atomic source for matter-wave interferometry in compact setups. Combining the production of quantum degenerate gases and magnetic field based atom optics for sample shaping, atom chips can provide atomic samples with effective temperatures in the lower nK regime. In this talk we present the realization of a Bragg diffraction based Mach-Zehnder like atom interferometer in our QUANTUS-I apparatus [1] using the chip surface as a retroreflector for the beam-splitting light fields. In a preliminary result we measure the gravitational acceleration with a resolution of $2 \cdot 10^{-4}\,g$ using spatially resolved interferometer read out.

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] Mütinga, Ahlers, Krutzik, Wenzlawski et al., PRL 110, 093602