Q 64: Matterwave Optics II

Time: Friday 14:00–16:00 Location: A 320

Q 64.1 Fr 14:00 A 320

Berry phase in atom optics — •Polina V. Mironova, Maxim A. Efremov, and Wolfgang P. Schleich — Universität Ulm, Ulm, Deutschland

We suggest to use the concept of the Berry phase to create an atomic lens. In particular, we consider the scattering of an atom by a near-resonant standing light wave, assuming an adiabatic turn-on and turn-off of the interaction. Within the rotating wave approximation and the adiabatic approximation on the atomic center-of-mass motion we find that the dynamical phase is cancelled out and the final state of the atom differs from the initial one only by twice the familiar Berry phase, which depends on the atomic external degrees of freedom. Therefore, the scattering process is determined by the atomic center-of-mass position.

Q 64.2 Fr 14:15 A 320

Distinction of structural isomers in molecule interferometry — •Sandra Eibenberger[1], Stefan Gerlich[1], Jens Tüxen[2], Marcel Mayor[2], and Markus Arndt[1] — [1]University of Vienna, Quantum Optics, Quantum Nanophysics, Quantum Information, Boltzmanngasse 5, 1090 Wien — [2]University of Basel, Department of Chemistry, St. Johannsring 19, CH-4056 Basel

Kapitza-Dirac Talbot-Lau interferometry (KDTLI) has already been established as a well-adapted tool for studying the quantum wave nature of massive and complex particles.

De Broglie coherence is to first order only associated with the center-of-mass motion. In the presence of external perturbations, quantum metrology however also becomes highly sensitive to internal molecular properties, such as electric susceptibilities or dipole moments, which may affect the interference contrast or phase shift without introducing genuine decoherence.

New high-contrast interference measurements now show for the first time the possibility to distinguish two structural isomers, i.e. two sorts of perfluoralkyl-functionalized molecules with the same mass (1592 amu) and the same chemical sum formula.

Q 64.3 Fr 14:30 A 320

High-Precision Matter-Wave Interferometry — •Naceur Gaaloul[1], Ernst Maria Rasel[1], and das QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Uni Bremen — [3]Institut für Physik, HU Berlin — [4]Institut für Laserphysik, Uni Hamburg — [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 recent developments in quantum optics transformed atom interferometry from pure fundamental research to a powerful technique giving birth to a multitude of tools for metrology, gravimetry and fundamental physics. Besides the measurement of fundamental constants (Fine structure constant, gravitational constants) or the tests of fundamental laws (Equivalence principle), the application of atom interferometers for gravimetry or generally for the measurement of inertial forces (Earth rotation, acceleration) became a central focus of research. Indeed, atom interferometers show not only a high sensitivity compared to other techniques but also an intrinsically high accuracy comparable to atomic clocks. Our efforts to advance the field of atom interferometry by carrying out challenging experiments, building networks and identifying the physical limitations as well as the potential applications will be reported in this contribution.

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 50WM0835-0839.

Q 64.4 Fr 14:45 A 320

Atom Interferometry in a mobile setup to measure local gravity — •Alexander Senger, Malte Schmidt, Matthias Hauth, Sebastian Grede, Christian Freier, and Achim Peters — Humboldt Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Hausvogteiplatz 5-7, 10117 Berlin

GAIN (Gravimetric Atom Interferometer) is a mobile and robust gravimeter, which is based on interfering ensembles of laser cooled ^{87}Rb atoms in an atomic fountain configuration. With a targeted accuracy of a few parts in 10^{10} for the measurement of local gravity, g, this instrument will offer about an order of magnitude improvement in performance over the best currently available absolute gravimeters. Together with the capability to perform measurements directly at sites of geophysical interest, this opens up the possibility for a number of interesting applications. Furthermore future satellite sensors based on atom interferometry will benefit from GAIN technology and experience.

We introduce the working principle of our interferometer and give an outline of the subsystems needed for a mobile setup. First measurements of local gravity acceleration are presented and the next steps necessary to achieve full accuracy are discussed.

Q 64.5 Fr 15:00 A 320

Space Atom Interferometer (SAI) — •Malte Schmidt[1], Guglielmo Tino[2], Philippe Bouyer[3], Ernst Rasel[4], Wolfgang Ertmer[4], Klaus Sengstock[5], Arnaud Landragin[6], Massimo Inguscio[7], Wolfgang Schleich[8], Reinhold Walser[8], Claus Laemmerzahl[9], Kai Bongs[10], and Achim Peters[1] — [1]Humboldt-Universität zu Berlin — [2]Università di Firenze — [3]Institut d'Optique, Orsay — [4]Institut für Quantenoptik, Hannover — [5]Universität Hamburg — [6]SYRTE, Paris — [7]LENS, Firenze — [8]Universität Ulm — [9]ZARM, Bremen — [10]University of Birmingham

Since 1992, matter wave interferometry has been used in many laboratories for a variety of fundamental physics experiments, e.g. measurement of the fine-structure and gravity constants. However, due to the complexity of these experiments, they were confined to laboratory environments. In recent years, however, efforts have been undertaken to develop mobile atom interferometers. These new sensors open up the possibility to perform on-site high-precision measurements of rotations, gravity gradients as well as absolute accelerations.

We present the SAI project (ESA contract 20578/07/NL/VJ) that investigates both experimentally and theoretically the different aspects of placing atom interferometers in space: the equipment needs, the resulting device sensitivities, and what physics might be done using such systems. For these purposes, the project brings together European institutions to share their mutual expertise and to collaborate on the construction of an atom interferometer testbed geared towards future applications in space. We give an overview of the sensor's ultra-compact design and report on the status of its first completed subsystems.

Q 64.6 Fr 15:15 A 320

Towards near-field interferometry with massive metal clusters — •Philipp Haslinger[1], Nadine Dörre[1], Philipp Geyer[1], Stefan Nimmrichter[1], Klaus Hornberger[2], Bernd v. Issendorff[3], and Markus Arndt[1] — [1]Faculty of Physics, University of Vienna, Austria — [2]Max-Planck Institute for the Physics of Complex Systems, Dresden, Germany — [3]Universität Freiburg, Germany

Throughout the last decade quantum interferometry with complex matter has grown from a Gedankenexperiment to a well developed field of research. Here we discuss the merits and draw-backs of far-field diffraction at material [1] and optical [2] gratings as well as a near-field interferometer that allows to increase both the detected flux as well as the mass limits in de Broglie interferometry [3,4]. A most promising instrument, at present, is an all-optical Talbot-Lau interferometer. It promises to shift matter wave interferometry to masses even beyond the limit of a million atomic mass units [5]. We discuss how such an interferometer can become important for exploring fundamental decoherence and dephasing phenomena and how it can become useful as a tool for measuring the electromagnetic or structural properties of nanoparticles [6].

[1] Arndt et al. Nature 401, 680 (1999) [2] O. Nairz et al. Phys. Rev. Lett. 87, 160401 (2001) [3]Brezger et al. Phys. Rev. Lett. 88, 100404 (2002) [4]Gerlich et al. NATURE PHYSICS 3, 711 (2007) [5]Reiger et al. Opt. Comm. 264, 326 332 (2006) [6]Gerlich et al. Angew.Chem.Int.Ed. 47, 6195 (2008)

Q 64.7 Fr 15:30 A 320

Quantum interference lithography with large molecules — •Philipp Geyer, Thomas Juffmann, Stefan Truppe, Sarayut Deachapunya, Andras Major, Hendrik Ulbricht, and Markus

Arndt — University of Vienna Austria

Already in the past, Talbot-Lau interferometry had proven to be a suitable tool for testing the wave-particle duality of complex and massive molecules.

We here report the implementation of a new detection scheme for molecule interferometry: the near-field interference pattern is deposited onto an atomically clean Si(111)7x7 surface, immobilized and subsequently imaged using a scanning tunnelling microscope (STM). We present interferograms of C60 buckyballs written onto the reconstructed silicon surface. STM imaging allows to detect every single molecule with nanometer resolution within the interference pattern. Dominantly applied as a detecting tool in quantum interference experiments molecule lithography also opens an interesting perspective on soft and non-contact surface deposition of molecular nanopatterns.

Q 64.8 Fr 15:45 A 320

The weak-coupling master equation of polarizable particles in a pumped cavity — •Stefan Nimmrichter[1], Klemens Hammerer[2], Helmut Ritsch[2], and Markus Arndt[1] — [1]Faculty of Physics, University of Vienna — [2]Institute for Theoretical Physics, University of Innsbruck

We derive a master equation for the motion of a polarizable particle weakly interacting with strongly pumped cavity modes. We follow the analogy to the light-pressure coupling model for the motion of cavity mirrors, while the particle motion is not considered to be deeply trapped in the optical potential. Focussing on massive particles with uncontrollable internal dynamics such as large molecules and clusters, our derivation bases on a phenomenological model of off-resonant particle-light interaction. The resulting friction and diffusion coefficients are in good agreement with former semiclassical calculations for atoms and small molecules in weakly pumped cavities, while the current rigorous quantum treatment is meant to throw light on the feasibility to optically manipulate beams of hot and massive particles.