Q 50: Matter Wave Optics

Time: Thursday 14:30–16:00 Location: P 11

Q 50.1 Thu 14:30 P 11

Light-shift effects in light-pulse atom interferometry —
•Alexander Friedrich[1], Enno Giese[2], Sven Abend[3], Wolfgang P. Schleich[1], and and Ernst M. Rasel[3] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm. — [2]Department of Physics, University of Ottawa. — [3]Institut für Quantenoptik, Leibniz Universität Hannover.

Light-pulse atom interferometry has become a formidable tool for high precision applications in quantum sensing and tests of fundamental physics. Nowadays interferometers of this type rely on either Bragg or Raman diffraction. Retro-reflective setups with two counter-propagating lattices reduce the effect of wave-front distortions and mirror vibrations. However, this advantage comes at the cost of a light-shift contribution to the interferometer phase due to off-resonant transitions. In Raman diffraction the impact of light-shifts is well understood.[1,2] For Bragg diffraction we have recently made significant progress and demonstrated that this intrinsic effect of beam splitters can be suppressed to a large extend by appropriately chosen pulse envelopes.[3] In our contribution we investigate mitigation strategies as well as different interferometer geometries.

[1] A. Gauguet et al., Phys. Rev. A **78**, 043616 (2008)
[2] T. Lévèque et al., Phys. Rev. Lett. **103**, 080405 (2009)
[3] E. Giese, A. Friedrich et al., Phys. Rev. A, (2016) (*accepted*)

A.F. is grateful to the Center for Integrated Quantum Science and Technology (IQ^{ST}) for funding.

Q 50.2 Thu 14:45 P 11

Interparticle interactions in atom interferometry —
•Christian Ufrecht, Albert Roura, Wolfgang P. Schleich, and the QUANTUS team — Institut für Quantenphysik, Universität Ulm

In recent years, high-precision atom interferometry has attracted a lot of attention. In particular, light pulse interferometers with macroscopic arm separations and Bose-Einstein condensates as highly coherent atom sources provide enormous potential to measure e.g. field gradients with unprecedented accuracy. Interactions between the atoms, however, seem to limit the precision in phase measurements and introduce mean-field shifts. To better understand these effects, we translate the formalism of Ref. [1] into second quantization, where the inclusion of interactions is straightforward. The choice of a particular interaction picture helps us to split the problem in two parts: (i) A free evolution which is equivalent to Ref. [1], and (ii) an interaction which acts upon this result. Our approach identifies the effects purely originating from the interaction.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number 50WM1556.

[1] Kleinert, S., Kajari, E., Roura, A. and Schleich, W. P., Phys. Rept. 605, 1-50 (2015)

Q 50.3 Thu 15:00 P 11

Excitation of Strongly Interacting Moving Rydberg Atoms by Photon Recoil Momentum — •Razmik Unanyan — University of Kaiserslautern, Germany

Based on isomorphism between an ensembles of Rydberg atoms in resonant laser fields in the limit of complete dipole blocking and the Jaynes-Cummings model we propose a scheme for robust and efficient excitation of atomic Rydberg state by photon-momentum recoil. It is shown that the Doppler frequency shifts, due to atomic motion can play an important role in adiabatic population transfer processes of atomic internal states by a pair of laser fields. For the limiting case of slow atoms (Doppler shift much smaller than the photon recoil energy) the Rydberg state does not become populated regardless of the order of switching of laser fields, while for the case of fast atoms interacting with the intuitive sequence of pulses, the target state is the state with single Rydberg excitation. It is shown that these processes are robust with respect to parameter fluctuations, such as the laser pulse area and the relative spatial offset (delay) of the laser beams.

Q 50.4 Thu 15:15 P 11

Discrete-Time Quantum Walks in Momentum Space —
•Caspar Groiseau[1] and Sandro Wimberger[1,2,3] — [1]ITP, Heidelberg University — [2]DiFeST, Parma University — [3]INFN, Sezione di Milano Bicocca, Gruppo Collegato di Parma

Quantum random walks differ from their classical analogue by the fact that the state of the walker is in a superposition of positions. This is the consequence of applying at each step of the walk a 'coin toss' operator that creates a superposition of two quantum states in an internal degree of freedom, followed by a conditional position displacement depending on this internal state. In our case, the walkers are atoms of a spinor Bose-Einstein condensate kicked by a periodic optical lattice, for whose description we can exploit the quantum kicked rotor dynamics. The kicks will act as the conditional displacements. For a simple zero-momentum initial state, the walker will just symmetrically diffuse in momentum space. We break the spatial-temporal symmetry by using a directed ratchet motion. The direction of the movement is controlled by the sign of the kicking potential. The sign difference in the kick potential corresponds to a sign difference in the detuning of the kicking laser between two hyperfine levels of the ground state. A concrete realization of this scheme with a Bose-Einstein condensate of Rubidium atoms is currently worked out at Oklahoma [1]. We investigate how the analytic theory of the temporal evolution of the quantum kicked rotor at quantum resonance can be transferred to two internal spin states that are mixed at each step.

[1] G. Summy and S. Wimberger, Phys Rev A 93, 023638 (2016)

Q 50.5 Thu 15:30 P 11

Electric Field Controlled Quantum Reflection — •Benjamin A. Stickler[1], A. Ronny Barnea[2], Tobias Nitschke[1], Uzi Even[2], and Klaus Hornberger[1] — [1]Faculty of Physics, University of Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany — [2]School of Chemistry, Sackler Faculty of Exact Sciences, Tel Aviv University, Tel Aviv 69978, Israel

We demonstrate that an electric potential can be used to control quantum reflection of matter waves off periodically microstructured surfaces. An alternating voltage applied between neighboring grating bars induces an electric field which serves to modify the interaction between the surface and the impinging atom so that quantum reflection is suppressed. The experimentally measured reflectivities agree with our simulations and the suppressed reflection probability is reproduced by a simple analytic model.

Q 50.6 Thu 15:45 P 11

Relativistic electron vortex beams in a magnetic field —
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We present a relativistic description of electron vortex beams in a constant magnetic field. Including spin from the beginning reveals a complicated azimuthal current structure, containing small rings of counterrotating current between rings of stronger corotating current. Contrary to many other problems in relativistic quantum mechanics, there exists a set of vortex beams with exactly zero spin-orbit mixing in the highly relativistic and nonparaxial regime. These 'clean' vortex beams possess no azimuthal currents and factorise in an azimuthal phase factor, or vortex charge, and a radial profile. A separation which is typically impossible for nonparaxial vortex beams of any nonzero spin.