Q 22: Matter Wave Optics II

Time: Monday 16:15–17:45 Location: K 1.013

Q 22.1 Mon 16:15 K 1.013

Testing Multi-path interference using molecule diffraction — •Christian Brand[1], Joseph Cotter[1], Christian Knobloch[1], Yigal Lilach[2], Ori Cheshnovsky[2], and Markus Arndt[1] — [1]Faculty of Physics, Boltzmanngasse 5, A-1090 Vienna, Austria — [2]Center for Nanoscience and Nanotechnology and School of Chemistry, Tel Aviv University, 69978 Tel Aviv, Israel

In quantum mechanics, the probability to measure a particle at a certain position is described by the square modulus of its wavefunction. This cornerstone of quantum-physics, known as Born's rule, underlies all quantum measurements, but is not immediately relevant for our classical world. In the search for a possible transition from quantum to classical phenomena, it has been proposed that the quantum mechanics may have non-linear extensions, giving rise to higher-order terms in multi-path interference [1]. This idea has been tested with mass-less photons with high accuracy [2]. Here, we present an explicit test of higher-order interference for the first time using massive organic molecules [3]. A thermal beam of phthalocyanine molecules was diffracted at a mask containing a combination of single-, double-, and triple-slits nanomachined into a 20 nm thin carbon membrane. From the analysis of the diffraction pattern in the matter-wave far-field, we deduce an upper bound for the possible contribution of higher-order interference for a wide region of molecular velocities of less than 1%.

[1] Sorkin, Mod. Phys. Lett. A **9**, 3119 (1994) [2] Urbasi, Science **329**, 418 (2010) [3] Cotter et al. Sci. Adv. **3**, 1607478 (2017)

Q 22.2 Mon 16:30 K 1.013

Polarization and mirror imperfections in retroreflective Raman– and Bragg diffraction — •Alexander Friedrich[1], Eric P. Glasbrenner[1], Enno Giese[2], Wolfgang P. Schleich[1], and Ernst M. Rasel[3] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, D–89069 Ulm. — [2]Department of Physics, University of Ottawa, K1N 6N5 Ottawa. — [3]Institut für Quantenoptik, Leibniz Universität Hannover, D–30167 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 for the beamsplitting process. Retroreflective setups with two counterpropagating lattices reduce the effect of wave–front distortions and mirror vibrations. However, as the miniaturization of atom interferometers progresses, even imperfect mirrors such as the atom chip surface may serve as a retroreflection mirror in typical experiments. In our talk we introduce a model to quantify the influence of non–perfect polarization orientation and mirrors on the diffraction of a matter wave inside such a retroreflective geometry.

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Q 22.3 Mon 16:45 K 1.013

Talbot-Lau interferometer for antimatter — •Andrea Demetrio[1], Simon R. Müller[1], Pierre Lansonneur[2], and Markus K. Oberthaler[1] — [1]Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany — [2]Institut de Physique Nucléaire de Lyon, CNRS/IN2P3, 69622 Villeurbanne, France

The Talbot-Lau interferometer has been used to perform measurements in the near-field regime with several different particle species in the past two decades. In order to deal with divergent, low intensity sources, such as currently available for antimatter, a large geometrical acceptance is desirable. We discuss that this directly translates into very stringent limits on the alignment of its components, depending on the diffusivity of the beam. Furthermore, when considering charged particles, the influence of external electric and magnetic fields plays a role in degrading the fringe visibility, especially as the length of the device increases. We present a concrete application of these principles to an experimental test setup with protons and discuss the implications for antimatter experiments.

Q 22.4 Mon 17:00 K 1.013

Aberrations of Bragg beam splitters - 3D simulations — •Antje Neumann and Reinhold Walser — Institut Angewandte Physik, TU Darmstadt, Deutschland

Atomic beam splitters are a central component of matter wave interferometers, which provide the opportunity of high-precision rotation and acceleration sensing. Potential applications range from fundamental physics to inertial navigation. In the QUANTUS free-fall experiments atom interferometry is the central method as well.

Beam splitters are used to prepare coherent superposition of atomic wave packets in momentum space by transferring photon momentum from a laser field. Clearly the aim of such devices is to cover a wide momentum range with unit response. Equivalent to optical systems all matter wave devices require accurate specifications and ubiquitous imperfections need to be quantified.

We focus on the response and aberrations of an atomic beam splitter in quasi Bragg configuration in 3D. In particular, we characterize the non-ideal behaviour due to spatial variations of the laser beam profiles and wave front curvatures, regarding realistic Gaussian laser beams instead of ideal plane waves. In addition, different temporal envelopes of the laser beam will be considered. We present results of numerical and analytical studies of the velocity dependence of the complex reflectivity of the beam splitter. Finally our theoretical results are confirmed by experimental data [1].

[1] M. Gebbe, Universität Bremen, Zarm, private communication.

Q 22.5 Mon 17:15 K 1.013

Coherence measurements of multiphoton-photoemitted electrons from tungsten nano tips — •Stefan Meier, Takuya Higuchi, Philipp Weber, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

Metal nanotips represent widely used coherent electron sources nowadays. By using them as dc field emission tips, an upper limit of their effective source size r_{eff} of only 0.4 nm was found [1]. This means that they show high spatial coherence properties, enabling matter-wave experiments, such as electron diffraction, holography or electron interferometry, as well as highest resolution electron microscopy. But electron emission from metal nanotips can also be triggered via photoemission. It was shown for tungsten nanotips that r_{eff} of electrons emitted in a single-photon emission process was almost as small as for dc field-emitted electrons under the same experimental conditions, so the supreme spatial coherence is maintained although the emission process is completely different [2]. By triggering the tips with femtosecond laser pulses it is possible to strongly confine the electron emission in time and therefore add high temporal resolution to these techniques. With the help of electron interference fringes after a CNT-based nanobiprism we here show results on characterizing the spatial coherence properties of electrons emitted via a nonlinear multiphoton photoemission process under illumination with few-cycle laser pulses.

[1] B. Cho *et al.*, Phys. Rev. Lett. **92**, 246103 (2004)
[2] D. Ehberger *et al.*, Phys. Rev. Lett. **114**, 227601 (2015)

Q 22.6 Mon 17:30 K 1.013

Quantum Limitation to the Coherent Emission of Accelerated Charges — •Alessandro Angioi and Antonino Di Piazza — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg

Accelerated charges emit electromagnetic radiation [1]. According to classical electrodynamics if the charges are sufficiently close to each other they emit coherently, i.e., their emission yield scales quadratically with the number of emitting charges rather than linearly. By investigating the emission by two-electron wave packets in the presence of an electromagnetic plane wave within strong-field QED [2], we show that quantum effects deteriorate the coherence predicted by classical electrodynamics even if the quantum nonlinearity parameter is much smaller than unity and classical and quantum results are expected to agree [3]. We explain this result by observing that coherence effects are also controlled by a new quantum parameter which relates the recoil undergone by the electron with the width of its wave packet in momentum space.

[1] J. D. Jackson, *Classical electrodynamics* (Wiley, New York, 1999).
[2] A. Di Piazza et al., *Rev. Mod. Phys.* **84**, 1177 (2012).
[3] A. Angioi and A. Di Piazza, *In preparation*.