Q 68: Matter Wave Optics I

Time: Friday 11:00–12:45 Location: K/HS2

Group Report Q 68.1 Fri 11:00 K/HS2

Impact of Casimir–Polder potentials on matter-wave interference at compact obstacles — •Stefan Yoshi Buhmann, Joshua Hemmerich, and Max Könne — Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

The Casimir–Polder interaction between an atom or molecule and a dielectric or metallic object arise due to the unavoidable zero-point fluctuations of the atomic or molecular electric dipole. As a consequence, the matter wave of a polarisable system is subject to a position-dependent Casimir–Polder potential in the vicinity of such objects. The resulting phase shift is manifest as a change of the interference pattern observed behind the scattering object.

We study Casimir–Polder potentials near dielectric discs and spheres in order to quantify their impact on matter-wave interference with Poisson-spot signals. The potentials are derived from macroscopic quantum electrodynamics, leading to exact solutions for spheres and Hamaker approximations for discs. Identifying different asymptotic regimes for the potentials, we discuss under which conditions nonretarded vs retarded Casimir–Polder potentials and edge effects for these potentials may potentially be observed and resolved in Poisson-spot experiments.

Q 68.2 Fri 11:30 K/HS2

Rotationally averaged Casimir-Polder forces — •Johannes Fiedler and Stefan Scheel — Institute of Physics, University of Rostock, D-18055 Rostock, Germany

Casimir-Polder forces between a microscopic particle and a macroscopic surface arise from the ground-state fluctuations of the quantized electromagnetic field. Commonly, the theoretical description of this interaction assumes the electric-dipole approximation in which the particle is represented by a point dipole [1]. However, recent interference experiments use large organic molecules at relatively high velocities which interfere on very thin material gratings [2]. A consequence of this set of parameters is that the molecules approach the grating surface very closely, at typical distances in the range of only a few nanometers, which implies that the molecules cannot be treated as point dipoles any longer. In order to cover the experimental situtation, we have developed a theory describing the interaction of large (i.e. spatially extended) molecules very close to surfaces. We employ the idea of Gaussian polarisability densities to include the size and shape of the molecule while retaining the dipole approximation [3]. We will investigate the effect of molecular rotation on the Casimir-Polder interaction during transit through the grating.

[1] S.Y. Buhmann, *Dispersion Forces I* (Springer, Heidelberg, 2012).
[2] T. Juffmann *et al.* Nature Nano **7**, 297 (2012).
[3] D.F. Parsons and B.W. Ninham, J. Phys. Chem. A **113**, 1141 (2009).

Q 68.3 Fri 11:45 K/HS2

Molecular interferometry at ultrathin nanogratings: from carbon nanoscrolls to a single layer of graphene — •Christian Brand[1], Michele Sclafani[1,5], Christian Knobloch[1], Yigal Lilach[2], Thomas Juffmann[3], Jani Kotakoski[1], Clemens Mangler[1], Andreas Winter[4], Andrey Turchanin[4,6], Jannik Meyer[1], Ori Cheshnovsky[2], and Markus Arndt[1] — [1]Faculty of Physics, University of Vienna, Austria — [2]School of Chemistry, Tel Aviv University, Israel — [3]Physics Department, Stanford University, USA — [4]Faculty of Physics, University of Bielefeld, Germany — [5]ICFO Institut de Ciències Fotòniques, Castelldefels, Spain — [6]Institute for Physical Chemistry, University of Jena, Germany

For quantum diffraction experiments with molecular matter-waves material gratings have the advantage that they are independent of the particle's internal properties. This makes them universally applicable. However, the molecules will experience substantial van der Waals shifts while passing the grating slits, which suggests limiting this perturbation by reducing the material thickness.[1] In a comprehensive study we compared the van der Waals interactions for ultrathin membranes including single and double layer graphene. From the population of high fringe orders we deduce a surprisingly strong electrical interaction between the polarizable molecules and the nanomasks. As even for these thinnest diffraction elements which-path information is not shared with the environment, we interpret this as an experimental affirmation of Bohr's arguments in his famous debate with Einstein.

[1] T. Juffmann *et al.*, Nat. Nano., **7** (2012)

Q 68.4 Fri 12:00 K/HS2

Diffraction of organic molecules at nanostructured gratings: the role of internal properties — •Christian Knobloch[1], Christian Brand[1], Michele Sclafani[2], Thomas Juffmann[3], Johannes Fiedler[4], Stefan Scheel[4], Yigal Lilach[5], Ori Cheshnovsky[5], and Markus Arndt[1] — [1]Faculty of Physics, University of Vienna, Austria — [2]ICFO Institut de Ciencies Fotoniques, Castelldefels, Spain — [3]Department of Physics, Stanford University, USA — [4]Institut für Physik,Universität Rostock, Germany — [5]School of Chemistry, Tel Aviv University, Israel

Quantum diffraction of matter-waves enhances the possibility to study the interaction between nanofabricated masks and delocalized molecules. To study these effects we use far-field diffraction at material gratings with single molecule resolution [1]. From the interference patters we are able to acquire information about different internal molecular properties. The interaction between the molecule and the walls of the material grating are mostly governed by dispersive forces. Beside that different experimental techniques allow to get knowledge about the polarizability, cross sections and other properties of the particle in the gas phase. Recent experiments in this field point to the importance of the role of permanent static dipole moments. Those are expected to increase the interaction by orders of magnitude and may lead to decoherence effects this way. This is of importance with regard to future quantum experiments with bio-molecules in the gas phase, that mostly exhibit such dipole moments.

[1] T. Juffmann et al., Nat. Nano., 7 (2012)

Q 68.5 Fri 12:15 K/HS2

Matter-wave interferometry with complex bionanomatter — •Philipp Geyer, Nadine Dörre, Jonas Rodewald, Philipp Haslinger, and Markus Arndt — Faculty of Physics, University of Vienna, Wien, Austria

We present recent results of Talbot-Lau interferometer with pulsed photodepletion gratings (OTIMA interferometry) and advances towards its combination with complex biomolecules. The interferometer uses three VUV laser light waves at 157 nm that are retro reflected on a single mirror to create three pulsed (7 ns) gratings[1]. The energy of each single photon suffices to ionize[2] or fragment[3] the particles that pass through the antinodes, while particles traveling through the nodes remain intact and in the beam. This way we obtain absorptive gratings that are precisely defined in time and space[4, 5]. They work independent of any particular electronic resonance in particles and avoid dispersive dephasing by van der Waals interactions that is often encountered in interaction with mechanical masks. We have performed interference experiments with various small biomolecular nanoparticles from vanillin to caffeine clusters and present new particle sources that will enable us to explore quantum interference assisted metrology on complex bio-molecules such as amino acids and large peptides.

1. Reiger E, et al. Opt Commun 2006, 264(2): 326-332.
2. Haslinger P, Geyer P, et al. Nature Physics 2013, 9: 144*148.
3. Dörre N, Geyer P, et al. Phys Rev Lett 2014.
4. Hornberger K, et al. Rev Mod Phys 2012, 84(1): 157-173.
5. Nimmrichter S, et al. New J Phys 2011, 13(7): 075002.

Q 68.6 Fri 12:30 K/HS2

High spatial coherence of laser-triggered electron pulses from metal nanotips — Dominik Ehberger[1,2], Jakob Hammer[1,2], Max Eisele[2], •Michael Krüger[1,2], Jonathan Noe[3], Alexander Högele[3], and Peter Hommelhoff[1,2,4] — [1]Department of Physics, Friedrich Alexander University Erlangen-Nuremberg, D-91508 Erlangen, Germany — [2]Max Planck Institute of Quantum Optics, D-85748 Garching, Germany — [3]Ludwig Maximilian University of Munich, D-80799 München, Germany — [4]Max Planck Institute for the Science of Light, D-91508 Erlangen, Germany

A spatially coherent source of laser-induced electron pulses is highly desirable for applications in ultrafast electron imaging and quantum optics with electronic matter waves. Metal nanotips are known to possess excellent coherence properties when operated as DC-field emitters and are widely used in electron imaging and holography. The spatial

coherence of a laser-triggered nanotip source of electrons, however, has not been quantified so far.

Here, we compare the coherence properties of a tungsten tip triggered by near-UV pulses and operated in DC-field emission. The effective source radius r_{eff} commonly used for quantifying spatial coherence is deduced from electron biprism interference patterns at a freestanding carbon nanotube. We measure $r_{\mathrm{eff}} \leq (0.80 \pm 0.05)$nm in laser triggered and $r_{\mathrm{eff}} \leq (0.55 \pm 0.02)$nm in DC-field emission, revealing that spatial coherence is nearly fully retained in a one-photon emission process. We expect that our findings have important consequences for ultrafast electron imaging.