Q 47: Quantum Effects (QED) II

Time: Thursday 10:30–12:15 Location: S Gr. HS Maschb.

Q 47.1 Thu 10:30 S Gr. HS Maschb.

The Impact of Geometry on Quantum Friction — •Christoph H. Egerland[1,2], Daniel Reiche[2], Francesco Intravaia[1], and Kurt Busch[1,2] — [1]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik & Photonik, Newtonstr. 15, 12489 Berlin, Germany — [2]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Max-Born-Str. 2A, 12489 Berlin, Germany

Quantum friction is a non-equilibrium dispersion force, evoked by electromagnetic vacuum fluctuations, that hinders the relative motion of interacting, but non-touching, objects. Since quantum friction has not been confirmed experimentally yet, a profound understanding of the mechanisms at work is essential for the design of suitable setups. For instance, modifying the material or geometry of the system's constituents reshapes the spectrum of the vacuum field and therefore the characteristics of the interaction.

In this work we investigate the quantative impact of the chosen geometry on the quantum frictional force experienced by microscopic particles.

Q 47.2 Thu 10:45 S Gr. HS Maschb.

Dispersion forces in inhomogeneous stratified media — •Johannes Fiedler[1,2], Clas Persson[2], and Stefan Yoshi Buhmann[1,3] — [1]Institute of Physics, University of Freiburg, Germany — [2]Centre for Materials Science and Nanotechnology, University of Oslo, Norway — [3]Freiburg Institute for Advanced Studies (FRIAS), Germany

Dispersion forces, such as van der Waals and Casimir forces are caused by ground-state fluctuations of the electromagnetic field and typically result in an attraction of the considered objects [1]. When describing these interactions with the methods of mQED, they are due to exchange of virtual photons [2]. An environment, as considered for instance in the context of possible repulsive forces, changes their scattering processes. Microscopic simulations of a particle embedded in a liquid shows a spatial distribution of the dielectric function [3].

We present an effectively one-dimensional model for dispersion forces in liquids taking into account such inhomogeneous dielectric profiles. The reflection coefficient will be approximated by analytical functions. This solution describes the impact of a local-field correction in analogy to cavity models. We illustrate the impact of the found model on the van der Waals and Casimir forces between two helium atoms and a two helium nano sheets embedded in water [4].

[1] H. B. G. Casimir, Proc. Kon. Nederland. Akad. Wetensch. B 51, 793 (1948). [2] S. Y. Buhmann Dispersion forces I, Springer (Heidelberg) 2012. [3] A. Held & M. Walter, J. Chem. Phys. 141, 174108 (2014). [4] J. Fiedler et al., submitted to PRA.

Q 47.3 Thu 11:00 S Gr. HS Maschb.

Dynamical nonequilibrium dispersion forces at finite temperatures — •Marty Oelschläger[1], Francesco Intravaia[2], and Kurt Busch[1,2] — [1]Max-Born-Institut, 12489 Berlin, Germany — [2]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik & Photonik, 12489 Berlin, Germany

If we leave the realm of closed system dynamics in equilibrium and step into the wide area of nonequilibrium physics of open systems, a vast number of new phenomena can be theoretically investigated and often experimentally observed. One interesting effect is a drag force acting on a particle when it is set in relative motion with respect to a surface. This phenomenon, usually called Casimir or quantum friction, is at the center of various discussions due to its peculiar nature and its connection to nonequilibrium physics. Current theoretical predictions are often restricted either to many approximations or to simplifying assumptions as, for example, a system at zero temperature. In our work we focus on the particle-surface interactions, where the particle can either be a non-dissipative atom or even a nanoparticle with an internal bath. We generalize the current theoretical framework describing quantum friction by considering finite temperatures, rotational degrees of freedom and/or a more realistic modeling of the nanoparticle's inner structure. With these extensions we aim towards an experimental realizable scheme in order to make quantum friction measurable.

Q 47.4 Thu 11:15 S Gr. HS Maschb.

Towards a spectroscopic measurement of quantum friction — •Nico Strauss[1], Johannes Fiedler[1,2], and Stefan Yoshi Buhmann[1,3] — [1]Institute of Physics, University of Freiburg, Germany — [2]Centre for Materials Science and Nanotechnology, University of Oslo, Norway — [3]Freiburg Institute for Advanced Studies (FRIAS), Germany

The Casimir–Polder force between atoms or molecules and is of quantum mechanical origin and forms the basis of quantum friction, which is predicted to occur when two objects move at distance on the order of nanometers relative to each other. In this presentation, we consider the effects of this force on the energy levels of atoms and their velocity dependence as well as that of the resulting transition frequencies [1]. We propose to investigate this frequency dependence in the experiments of M. Ducloy and M. Fichet [2] by measuring the changes in the reflection coefficients of a modulated laser beam incident on the boundary between a dielectric and a gas of moving atoms.

[1] J. Klatt, R. Bennett and S. Y. Buhmann, Phys. Rev. A **94**, 063803 (2016).

[2] M. Ducloy and M. Fichet, J. Phys. **II**, 1529 (1991).

Q 47.5 Thu 11:30 S Gr. HS Maschb.

Ab-initio few-mode Hamiltonians for cavity QED — •Dominik Lentrodt, Kilian P. Heeg, Christoph H. Keitel, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Few-mode models, such as the Jaynes-Cummings model, have been an indispensable tool in studying the quantum dynamics of light-matter interactions. In particular in cavity and circuit QED these models have been tremendously successful and have been employed in combination with the famous input-output formalism to compute, for example, scattering observables. Recently, however, extreme regimes, such as overlapping modes and ultra-strong coupling, have become accessible experimentally. In these regimes the applicability of input-output models has been debated [e.g. 1,2]. In this talk we will present an ab-initio method to construct few-mode Hamiltonians that apply even in such extreme regimes. Our theory extends the validity range of Jaynes-Cummings type models without abandoning their conceptual and computational simplicity. We show that the input-output formalism can be used to rigorously reconstruct the scattering information from such few-mode Hamiltonians, if a background contribution is accounted for. This enables the connection to a large body of theoretical methods that are based on few-mode and input-output models, which can now be applied in an ab-initio way. We will outline some implications, in particular for X-ray cavities, where new effects have already been observed [3]. Potential applications include quantum optics with exceptional points [4]. [1] Dutra *J Opt B* (2000) [2] Bamba *PRA* (2013) [3] Heeg et al *PRL* (2013) [4] El-Ganainy et al *Nature Physics* (2018)

Q 47.6 Thu 11:45 S Gr. HS Maschb.

Cold-atom-based implementation of the Dicke model in the ultra-strong coupling regime — •Yijian Meng[1], Alexandre Dareau[1], Philipp Schneeweiss[1], and Arno Rauschenbeutel[1,2] — [1]TU Wien-Atominstitut,Vienna, Austria — [2]Department of Physics, Humboldt-Universität zu Berlin, Berlin, Germany

We realize a mechanical analogue of the Dicke model, achieved by coupling the spin of individual neutral atoms to their quantized motion in an optical trapping potential [1]. The atomic spin states play the role of the electronic states of the atomic ensemble considered in the Dicke model, and the in-trap motional states of the atoms correspond to the states of the electromagnetic field mode. The coupling between spin and motion is induced by an inherent polarization gradient of the trapping light fields [2], which leads to a spatially varying vector light shift. We experimentally show that our system reaches the ultra-strong coupling regime, i.e., we obtain a coupling strength which is a significant fraction of the trap frequency. Moreover, with the help of an additional light field, we demonstrate the in-situ tuning of the coupling strength. Beyond its fundamental interest, the demonstrated one-to-one mapping between the physics of optically trapped cold atoms and the Dicke model paves the way for implementing protocols and applications that exploit extreme coupling strengths.

[1] A. Dareau, Y. Meng, P. Schneeweiss, A. Rauschenbeutel, arXiv:1809.02488

[2] P. Schneeweiss, A. Dareau, and C. Sayrin, Phys. Rev. A 98, 021801(R) (2018)

Q 47.7 Thu 12:00 S Gr. HS Maschb.

Selforganization of magnetic atoms in an optical cavity — •Luigi Giannelli, Simon Jäger, and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany

We theoretically analyse the dynamics of cold atomic spins in a single-mode standing-wave cavity as a function of the intensity and phase of the transverse laser, driving the atoms. We identify and discuss the conditions under which stable spatial patterns form, where atomic position and magnetization are correlated. We discuss the properties of the light emitted by the cavity as a method to reveal the state of the atomic vapor.