Q 31: Quantum Effects (QED)

Time: Tuesday 14:00–15:45 Location: K 1.013

Q 31.1 Tue 14:00 K 1.013

Statistical and Geometrical Aspects of Atom-Surface Interaction in Dynamical Nonequilibrium — •Daniel Reiche[1,2], Francesco Intravaia[2], 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

The energy contained in fluctuations exactly equates that lost in dissipation, if both the system of interest and its environment are in thermodynamic equilibrium. This quantitative balance is a remarkable feature of open (quantum) systems and often serves as a conceptual basis for describing nonequilibrium situations. Indeed, it is commonly assumed that despite the system equilibrates not as a whole, separated subsystems equilibrate locally with their immediate surroundings. Relying on equilibrium results significantly reduces the technical complexity of computations, but neglects long-range correlations.

In the context of atom-surface interaction, we study the impact of nonequilibrium physics on quantum friction as well as Casimir-Polder interaction for planar geometries, e.g. a single half-space or a planar cavity. Considering a linear response of the particle to electromagnetic perturbations, we do not rely on any particular assumption on statistical measures such as Markovianity or Local Thermal Equilibrium. We place a special emphasize on the interplay between the chosen setup and the influence of nonequilibrium.

Q 31.2 Tue 14:15 K 1.013

Atom-surface interactions with nonlocal materials — •Francesco Intravaia[1], Daniel Reiche[1,2], and Kurt Busch[1,2] — [1]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Max-Born-Str. 2A, 12489 Berlin, Germany — [2]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik & Photonik, Newtonstr. 15, 12489 Berlin, Germany

The interaction between an atom and an extended body, such as a surface, is one of the oldest but also one of the most relevant problem of quantum physics. Indeed, due to the technological progress of recent years, atoms can be placed closer and closer to a material interface, which opens new horizons for quantum technologies and quantum-sensing. In this regime, however, some of the some of the simplifying assumptions used so far in the description of atom-surface interactions start to loose their validity. In particular the spatial dispersive properties of the material, neglected in most of the of the investigations reported in the literature, start to play a relevant role. Phenomena, such as the Landau damping, and new length scales, like the carrier's mean free path or the Thomas-Fermi screening length, induce fascinating behaviors which are completely absent in a local description of the electro-optical properties of the material.

We discuss here some relevant effects and recent results, which show the relevance of spatial dispersion in atom-surface interactions. The focus is on dispersion forces (non-charged objects) and on the interplay of nonlocality with quantum mechanics and nonequilibrium physics.

Q 31.3 Tue 14:30 K 1.013

Tailoring Quantum Friction with Superlattice Structures — •Marty Oelschläger[1,2], Francesco Intravaia[2], 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 drag force mediated by the electromagnetic vacuum fluctuations acting on an object in relative motion with respect to another. The characteristics of this interaction depend on the physical properties of the bodies as well as their details of the nano-structures. Here, we address two connected aspects of this non-equilibrium dispersion force: its strength and its behavior as a function of the kinematic and geometrical parameters that characterize the system. Specifically, we investigate the electromagnetic response of a superlattice structure, focusing on the low frequency plasmonic properties of the system and on the corresponding electromagnetic density of states. Since quantum friction strongly depends on these features, by tailoring the properties of the material we can control the drag force.

Q 31.4 Tue 14:45 K 1.013

Dispersion forces in multi-layered media — •Johannes Fiedler[1,2] and Stefan Y. Buhmann[1,3] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany — [2]Centre for Materials Science and Nanotechnology, Department of Physics, University of Oslo, Oslo, Norway — [3]Freiburg Institute for Advanced Studies, Universität Freiburg, Freiburg, Germany

Dispersion forces are a result of the zero-point fluctuations of the electromagnetic field and are typically attractive for ground-state particles [1]. However, the presence of a medium environment allows for repulsion depending on the optical densities in the particular system. We present a method describing dispersion forces in planar multi-layered systems with continuous dielectric profile and illustrate the impact on Casimir and van der Waals forces with respect to the shape of the inhomogeneity [2]. For particles embedded in a medium we assume a cavity surrounding the particles to account for the impact of Pauli repulsion [3]. A combination of both methods can be applied to nanosized ice particles below the ocean's surface. In this situation one finds a repulsive force with respect to the surface that prevents the particle from passing through the surface [4]. Depending on their size the particles levitate at specific distances to the surface due to the balance of buoyancy, Casimir-Polder and salt forces. Further, we illustrate the possibility of capturing methane in thin water layers surrounding ice.

[1] S.Y. Buhmann, Dispersion forces I (Springer Heidelberg, 2012). [2] J. Fiedler et al., in preparation. [3] J. Fiedler et al., J. Phys. Chem. A in press (2017), arXiv: 1710.04945. [4] P. Thiyam et al., in preparation.

Q 31.5 Tue 15:00 K 1.013

Casimir Force and Torque for Nonreciprocal Media and Applications to Photonic Topoligical Insulators — •Frieder Lindel[1,2], Sebastian Fuchs[1,2], and Stefan Yoshi Buhmann[1,3] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [2]Department of Chemistry, University of British Columbia, Vancouver, British Columbia V6T 1Z1, Canada — [3]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität Freiburg, Albertstraße 19, 79104 Freiburg, Germany

The Casimir force was originally proposed as an attractive force between two perfectly conducting plates due to a reduced virtual photon pressure in the space between the plates. In macroscopic quantum electrodynamics (QED) the Casimir force was further generalised to bodies of arbitrary shape and material by realising that its existence stems from fluctuating charge carries within the materials.

We derive an even more general expression of the Casimir force within this framework of macroscopic QED for the case of bodies which break the Lorentz reciprocity condition and thus violate time reversal symmetry. We apply our result to a certain photonic topological insulator media, namely magnetised plasma with a static bias magnetic field to find that the Casimir force can be tuned by controlling the bias field. We further show that for certain configurations there exists a tunable Casimir torque which shows unique features due to unidirectional surface plasmons provided by the topological structure of the material.

Q 31.6 Tue 15:15 K 1.013

Plasma vs Drude modelling of the Casimir force: beyond the proximity force approximation — •Michael Hartmann[1], Gert-Ludwig Ingold[1], and Paulo A. Maia Neto[2] — [1]Universität Augsburg, Institut für Physik, 86135 Augsburg — [2]Instituto de Física, UFRJ, Rio de Janeiro, Brazil

We calculate the Casimir force and its gradient between a spherical and a planar gold surface [1]. Significant numerical improvements allow us to extend the range of accessible parameters into the experimental regime. We compare our numerically exact results with those obtained within the proximity force approximation (PFA) employed in the analysis of all Casimir force experiments reported in the literature so far. Special attention is paid to the difference between the Drude model and the dissipationless plasma model at zero frequency. It is found that the correction to PFA is too small to explain the discrepancy between the experimental data and the PFA result based on the Drude model. However, it turns out that for the plasma model, the corrections to PFA lie well outside the experimental bound obtained by probing the variation of the force gradient with the sphere radius [2]. The corresponding corrections based on the Drude model are significantly smaller but still in violation of the experimental bound for small distances between plane and sphere.

[1] M. Hartmann *et al.*, Phys. Rev. Lett. **119**, 043901 (2017)
[2] D. E. Krause *et al.*, Phys. Rev. Lett. **98**, 050403 (2007)

Q 31.7 Tue 15:30 K 1.013

A derivation of the resonance fluorescence spectrum with the resolvent-operator formalism

— •Vincent Debierre and Zoltán Harman — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg

It is known that the spectrum of the light scattered by a two-level atom (the so-called Mollow spectrum) exhibits very different profiles in different intensity regimes. In particular, the incoherently scattered fraction of the incoming light is subdominant at low intensities and dominant at high intensities. Mollow has shown that the incoherent part takes over when the Rabi frequency of the light-atom interaction becomes larger than the natural linewidth of the excited atomic state. We derived [V. Debierre and Z. Harman, Phys. Rev. A **96**, 043835 (2017)] the Mollow spectrum in the resolvent operator formalism. The derivation is based on the construction of a master equation from the resolvent operator of the atom-field system. We show that, for electric dipole transitions, the natural linewidth of the excited atomic level remains essentially unmodified, to a very good level of approximation, even in the strong-field regime, where Rabi flopping becomes relevant inside the self-energy loop that yields the linewidth, ensuring that the obtained master equation and the spectrum derived matches that of Mollow. On the other hand, for non-electric dipole transitions (that can still be treated within the framework of the two-level approximation), our formalism predicts important modifications to the lifetime of the excited state in the strong-driving case.