A 4: Quantum Effects (QED) (joint session Q/A)

Time: Monday 11:00–13:00 Location: F442

A 4.1 Mon 11:00 F442

In the eye of the beholder: Interference in multi-atom dynamics — •Stefan Yoshi Buhmann[1] and Janine Franz[1,2] — [1]University of Kassel, Germany — [2]University of Freiburg, Germany

The Casimir–Polder force between an excited with a ground-state atom had been subject to an old controversy: Does its distance dependence exhibit oscillations due to interference [1] or not [2]? A time-dependent analysis of this scenario has revealed that the correct answer is a matter of perspective: the force on the excited atom does oscillate while that on the ground-state atom does not [3].

We complete this picture by studying the rate with which the excitation of the atom gets lost or is transferred to the ground-state atom, considering a range of channels: environment-assisted spontaneous decay, resonance energy transfer, and Auger decay. Again, we find that the correct answer depends on the perspective and hence the specific process considered.

[1] L. Gomberoff, R. R. McLone, and E. A. Power, J. Chem. Phys. **44**, 4148 (1966).
[2] E. A. Power and T. Thirunamachandran, Phys. Rev. A **47**, 2539 (1993).
[3] P. Barcellona, R. Passante, L. Rizzuto, and S. Y. Buhmann, Phys. Rev. A **94**, 012705 (2016).

A 4.2 Mon 11:15 F442

Quantum friction near nonreciprocal media and chiral media — •Omar Jesús Franca Santiago and Stefan Yoshi Buhmann — Institute of Physics, University of Kassel, Germany

We investigate how the quantum friction experienced by a polarisable charged particle moving with constant velocity parallel to a planar interface is modified when the latter consists of a chiral media or nonreciprocal media, with special focus on topological insulators. We use macroscopic quantum electrodynamics to obtain the Casimir-Polder frequency shift and decay rate. These results are a generalization of the respective quantities to matter with time-reversal symmetry breaking which violates the Lorentz reciprocity principle. We illustrate our findings by examining the nonretarded and retarded limits for five examples: a perfectly conducting mirror, a perfectly reflecting nonreciprocal mirror, a three-dimensional topological insulator, a perfectly reflecting chiral mirror and an isotropic chiral medium.

[1] Stefan Yoshi Buhmann, David T. Butcher and Stefan Scheel. New Journal of Physics 14, 083034 (2012).
[2] Sebastian Fuchs, J. A. Crosse and Stefan Yoshi Buhmann. Phys. Rev. A 95, 023805 (2017).
[3] David T. Butcher, Stefan Y. Buhmann, Stefan Scheel, New Journal of Physics 14, 113013 (2012).

A 4.3 Mon 11:30 F442

Casimir free energy of two bi-isotropic spheres in the plane-wave approach — •Tanja Schoger[1], Benjamin Spreng[2], Gert-Ludwig Ingold[1], and Paulo A. Maia Neto[3] — [1]Universität Augsburg, Augsburg, Germany — [2]University of California, Davis, USA — [3]Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil

The Casimir interaction between two bi-isotropic spheres, where polarization mixing upon reflection at each sphere occurs, is studied in the plane-wave approach. We demonstrate that an asymptotic expansion of the Casimir force for large spheres, compared to the surface-to-surface distance, leads to the proximity force approximation (PFA) of the Casimir interaction [1].

A special case of bi-isotropic spheres are perfect electromagnetic conductors (PEMC) interpolating between the spheres with infinite permittivity and infinite permeability for which we present results for vanishing as well as non-zero temperatures [1, 2]. Apart from the PFA results, we also determine the leading PFA corrections and the results for large distances which reveal that the transition from an attractive force to a repulsive force depends on the temperature and the distance between the spheres.

[1] T. Schoger, B. Spreng, G.-L. Ingold, P. A. Maia Neto, Int. J. of Mod. Phys. A 37, 2241009 (2022)
[2] S. Rode, R. Bennett, S. Y. Buhmann, New J. Phys. 20, 043024 (2018)

A 4.4 Mon 11:45 F442

Heat transport using nonreciprocal media — •Nico Strauss, Stefan Yoshi Buhmann, and Omar Jesús Franca Santiago — Institute of Physics, University of Kassel, Germany

The second law of thermodynamics dictates that heat flows from warm to cold objects, thereby providing a direction of time [1]. In the optics of nonreciprocal media [2], an arrow of time is alternatively provided by the observation that optical paths cannot be reversed. How are these two notions compatible of the level of quantum electrodynamics? In order to answer this question, we calculate the nanoscale heat transfer between the surfaces of two nonreciprocal media, namely axionic topological insulators which exhibit a temperature difference $\Delta\mathrm{T} = \mathrm{T}_1 - \mathrm{T}_2$. We investigate the impact of the nonreciprocal properties of the plates on the heat transfer and investigate their interplay with the second law in the near field.

[1] Volokitin, A. I.; Persson, B. N. J. Rev. Mod. Phys. **4**, 79 (2007)
[2] S. Y. Buhmann et al., New J. Phys. **14**, 083034 (2012).

A 4.5 Mon 12:00 F442

The Casimir-Polder force near an elliptical nanowire — •Bettina Beverungen[1], Kurt Busch[1,2], and Francesco Intravaia[1] — [1]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik & Photonik, Newtonstr. 15, 12489 Berlin, Germany — [2]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Max-Born-Str. 2 A, 12489 Berlin, Germany

Quantum and thermal fluctations of the electromagnetic field lead to many highly interesting and nontrivial effects such as the emergence of forces between neutral objects. These persist even in the limit of zero temperature due to the irreducible nature of the quantum fluctuations. While these interactions typically fall off rapidly with distance, they play a significant role at short separations relevant for modern nanotechnological applications. It is therefore important to understand how they depend on the geometry and material properties of the objects involved.

A prominent example is the Casimir-Polder force, which describes the interaction between a neutral atom or nanoparticle and a macroscopic object. Here, we investigate this interaction for an atom near a metallic nanowire of elliptical cross section. To verify the validity of our results, we show that they reduce to the case of a circular nanowire for low ellipticities. As a way to gain additional insight into the problem, we analyze the asymptotic behavior of the interaction energy with a particular focus on the distance regime where the effect of curvature is most pronounced.

A 4.6 Mon 12:15 F442

Constraints on Beyond-Standard-Model Particles from the Muon's Anomalous Magnetic Moment — •Clive Reese and Stefan Yoshi Buhmann — University of Kassel, Germany

While the Standard Model is incredibly successful in predicting the anomalous magnetic moment of the electron, the same theory fails at predicting the anomalous magnetic moment of the muon a_μ. Recent experimental results by Fermilab reinforce the discrepancy, displaying a deviation of $4.2\,\sigma$ [1]. Particles Beyond Standard Model (BSM) can contribute to a_μ due to one-loop corrections and thus explain the anomaly.

In our work we assume one fermion and one (pseudo-)scalar particle in the interaction, where either one of the particles or both can be BSM particles. We calculate the contribution to a_μ in dependence of the masses, coupling constants and electric charges. Considering experimental and theoretical limits it turns out that chiral couplings constitute good candidates, while uncharged fermions like neutrinos cannot explain the anomaly. A scalar in PeV-Scale is too heavy to be detected, but an theoretically explain the anomaly.

[1] B. Abi et al.: 'Measurement of the Positive Muon Anomalous Magnetic Moment to 0.46 ppm', Phys. Rev. Lett. **126**, 141801 (2021)

A 4.7 Mon 12:30 F442

Influence of quantum vacuum fluctuations on the causality of field correlations within nonlinear crystals — •Cristofero Oglialoro[1], Frieder Lindel[2], Fabian Spallek[1], and Stefan Yoshi Buhmann[1] — [1]University of Kassel, Germany — [2]University of Freiburg, Germany

A major consequence of Heisenberg's uncertainty principle is that, even though the expectation value of a quantum field vanishes, its ground state exhibits so-called quantum vacuum fluctuations. In recent years, experimental progress has made it possible to study the ground state fluctuations through electro-optic sampling by measuring changes in the polarisation of a laser pulse passing through a nonlinear crystal. The rotation of the polarisation can be attributed to the interaction of the pulse with the quantum vacuum. Macroscopic QED allows to describe the changes in this vacuum structure induced by the interaction with dielectric macroscopic bodies and provides a theoretical framework to survey its physical signatures. Studies of the correlation of the field of two laser pulses in a nonlinear crystal have even shown that points causally disconnected according to special relativity can exhibit a nonvanishing correlation function due to the interaction with the vacuum fluctuations [1]. We want to further investigate the influence of the quantum vacuum on the causality of correlations within dielectric macroscopic bodies and the possibility to explore the space-time structure of vacuum correlations in the altered metric provided by a nonlinear crystal in analogy to the behaviour in curved space-time.

[1] F. F. Settembrini, et al., Nat. Commun. 13, 3383 (2022).

A 4.8 Mon 12:45 F442

Dispersive and dissipative dielectrics with 'scalar-field' type environments — •Sascha Lang[1,2,3], Stefan Yoshi Buhmann[1], Ralf Schützhold[2,4,3], and William G. Unruh[5,6] — [1]University of Kassel, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [3]Universität Duisburg-Essen, Germany — [4]Technische Universität Dresden, Germany — [5]University of British Columbia, Canada — [6]Texas A&M University, United States

Macroscopic quantum electrodynamics provides a powerful framework for studying a large variety of dispersive and dissipative media [1]. To account for quantum fluctuations, a noise polarisation is manually incorporated into the formalism. This phenomenological approach is inspired by microscopic derivations (based on, e.g., the famous Huttner-Barnett model [2]) which explicitly describe damping via interactions with baths of harmonic oscillators. Unfortunately, models with harmonic-bath type environments are usually quite involved and facilitate straightforward solutions only for time independent systems and in the case of relatively simple position dependences.

We present an alternative approach and model dissipation via a scalar field that may carry energy and information away from the medium [3,4]. This model is much simpler than established microscopic descriptions and still holds for explicitly time-dependent systems.

[1] Scheel & Buhmann, Acta Phys. Slov. **58**, 675 (2008)
[2] Huttner & Barnett, PRA **46**, 4306 (1992)
[3] Lang, Schützhold & Unruh, PRD **102**, 125020 (2020)
[4] Lang, Sauerbrey, Schützhold & Unruh, PRR **4**, 033074 (2022)