Q 71: Quantum Effects: QED IV

Time: Friday 14:30–16:30 Location: f442

Group Report Q 71.1 Fri 14:30 f442

New effects in surface-dependent vacuum QED — •Robert Bennett[1], Juliane Klatt[1], Adam Stokes[2], Stefan Buhmann[1], and Claudia Eberlein[3] — [1]University of Freiburg, Germany — [2]University of Leeds, United Kingdom — [3]University of Sussex, Brighton, United Kingdom

Quantum electrodynamics (QED) is the remarkably successful theory of the interaction of light and matter. It shows unprecedented levels of agreement with experiment, with the most famous example being the anomalous magnetic moment of the electron, where theory and experiment have found consistency up to one part in 10 trillion. In order to design the next generation of precision tests of QED, the effect the extended material objects have on the fundamental properties of atoms and electrons in their vicinity must be quantified to ever-increasing precision. The main part of the presentation will be an outline of new developments in one of these effects, namely the surface-dependent shift in the anomalous magnetic moment of an electron [1]. Following this there will be a brief presentation of some experimentally-focused work concerning motional atomic level shifts and decay rates near complex nanostructures [2], as well as an account of a recently-developed unified approach to Casimir forces for fields carrying arbitrary spin [3] in which the well-known electromagnetic Casimir force emerges as a special case.

[1] R. Bennett & C. Eberlein New J. Phys. 14 123035 (2012) [2] R. Bennett: Phys. Rev. A 92, 022503 (2015) [3] A. Stokes & R. Bennett New J. Phys. 17, 073012 (2014)

Q 71.2 Fri 15:00 f442

Casimir–Polder interaction and symmetry breaking — •Stefan Yoshi Buhmann[1], Valery N. Marachevsky[2], and Stefan Scheel[3] — [1]Freiburg University, Freiburg, Germany — [2]St. Petersburg University, St. Petersburg, Russia — [3]Rostock University, Rostock, German

Casimir–Polder interactions between atoms and surfaces are due to correlated quantum fluctuations of the atomic charge density and the electromagnetic field. Using second-order perturbation theory within the framework of macroscopic quantum electrodynamics, they can be expressed in terms of the electromagnetic response of the atoms on the one hand and the surface on the other [1].

We show that the Casimir–Polder potential can be used to probe unusual properties of both interacting objects, such as the violation of fundamental symmetries. To that end, we consider CP-violating atoms interacting with a perfect T-violating mirror or a plane surface with Chern–Simons interaction [2].

[1] S. Y. Buhmann, *Dispersion Forces I* (Springer, Heidelberg, 2012).

[2] S. Y. Buhmann, V. N. Marachevsky, S. Scheel, *CP-violating CP interactions*, in preparation (2015).

Q 71.3 Fri 15:15 f442

Medium-assisted Casimir–Polder interaction between chiral molecules — •Pablo Barcellona and Stefan Yoshi Buhmann — Institute of Physics, Freiburg University, Germany

Using second-order perturbation theory with an effective Hamiltonian, we calculate the Casimir–Polder force between two ground-state chiral molecules at zero temperature in the presence of magnetodielectric bodies. In free space, the Casimir–Polder force has a small chiral component depending on both electric and magnetic transitions. With the presence of a material environment we find some highly symmetric configurations where the electric and magnetic contributions of the Casimir–Polder force cancel, making the chiral component the dominant contribution. This is achieved via magnetoelectric plates which exhibit chiral properties. The dominant chiral Casimir–Polder force is discriminatory with respect to enantiomers of different handedness.

Q 71.4 Fri 15:30 f442

Casimir–Polder interaction of neutrons with surfaces — •Valentin Gebhart, Juliane Klatt, and Stefan Yoshi Buhmann — Albert-Ludwigs-University, Freiburg, Deutschland

Searching for an example of the elusive repulsive dispersion force we study the Casimir–Polder interaction of a neutron with a metal or dielectric plate. By using macroscopic quantum electrodynamics and perturbation theory we examine the position-dependent potential of the magnetizable neutron in front of a plate with arbitrary dielectric properties. We indeed find a purely repulsive dispersion interaction whose amplitude is very sensitive to the model used for the plate permittivity. Finally, we discuss the relevance of the proposed interaction in neutron-interferometry experiments [1].

[1] H. Rauch, H. Lemmel, M. Baron, R. Loidl, *Measurement of a confinement induced neutron phase*, Nature **417**, 630 (2002).

Q 71.5 Fri 15:45 f442

From Casimir-Polder Force to Dicke Physics: Interaction between Atoms and a Topological Insulator — •Sebastian Fuchs[1], Stefan Yoshi Buhmann[1], and John Alexander Crosse[2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [2]Department of Electrical and Computer Engineering, National University of Singapore, 4 Engineering Drive 3, Singapore 117583

We apply the theory of macroscopic quantum electrodynamics in dispersing and absorbing media to study the Casimir-Polder force between an atom and a topological insulator [1]. The electromagnetic response of a topological insulator surface leads to a mixing of electric and magnetic fields, breaking time-reversal symmetry [2, 3]. The coupling of these fields to an atom causes shifts of the atom's eigenenergies and modified decay rates near the surface of the topological insulator. Energy shifts and modified decay rates cannot only be triggered by the presence of a material, but can be caused by other atoms in close proximity as well. The collective dynamics of atoms (Dicke Physics) leads to a superradiant burst [4]. Combining macroscopic QED and Dicke physics opens the door to the investigation of cooperative atom-surface interactions. [1] S. Y. Buhmann, Dispersion Forces II, Springer-Verlag Berlin Heidelberg (2012). [2] S. Y. Buhmann, D. T. Butcher, and S. Scheel, New Journal of Physics 14, 083034 (2012). [3] J. A. Crosse, S. Fuchs, and S. Y. Buhmann, Physical Review A, in print, arXiv: 1509.03012 (2015). [4] S. Fuchs, J. Ankerhold, M. Blencowe, and B. Kubala, arXiv: 1501.07841 (2015).

Q 71.6 Fri 16:00 f442

Paraxial Theory of Direct Electro-Optic Sampling of the Quantum Vacuum — •Andrey S. Moskalenko, Claudius Riek, Denis V. Seletskiy, Guido Burkard, and Alfred Leitenstorfer — Department of Physics and Center for Applied Photonics, University of Konstanz, Germany

The quantum vacuum is one of the most fundamental states of light and matter fields. Quantum mechanics teaches us that the vacuum is not just empty space: E.g., in the vacuum state, even in the absence of any photons, the electromagnetic field is not strictly zero but fluctuates. A fundamental question is whether and how one can access these fluctuations directly. Despite many indirect measurements, this question has remained open until very recently [1].

We theoretically show that vacuum fluctuations of the electric field in free space can be directly detected using the linear electro-optic effect [2]. We demonstrate that the fluctuations in the ground state lead to an increase of the measured signal variance on top of the shot noise and can be directly resolved, as experimentally confirmed [1]. Furthermore, applying the theory to a squeezed vacuum state, we predict that temporal oscillations of the electric field noise, significantly beating the pure vacuum level, can be traced with sub-cycle resolution [2]. We believe that our findings pave the way for an approach to quantum optics operating in an extreme time-domain limit, providing access to quantum statistics of light on a sub-cycle time scale.

[1] C. Riek et al., Science 350, 420 (2015).

[2] A.S. Moskalenko et al., arXiv:1508.06953, accepted in PRL.

Q 71.7 Fri 16:15 f442

Lateral Casimir–Polder forces — •Ricardo Oude Weernink and Stefan Yoshi Buhmann — Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

Lateral Casimir–Polder forces can occur when excited-state atoms undergo asymmetric downward circular dipole transitions [1]. Lateral in this regard means parallel to the surface of a metal or dielectric body. As recently observed for the case of a nanofiber, the atoms' decay leads to asymmetrically emitted fields [2], causing this force.

We study this effect for a simple model geometry: an excited two-state atom is positioned in a vacuum half space close to a half space filled with homogeneous dielectric. By use of macroscopic quantum electrodynamics, the lateral force can be described as a fuction of the system's Green's tensor and the atomic dipole moment. Also, a non-vanishing asymmetry term for photons being emitted into the two lateral half spaces can be established. This asymmetry explains the physical origin of the force by virtue of conservation of momentum. Both the force as well as the emission asymmetry show an oscillating behaviour in space, with the oscillations being related to the wave-length of the emitted photons.

[1] *Directional spontaneous emission and lateral Casimir-Polder force on an atom close to a nanofiber*, S. Scheel, S. Y. Buhmann, C. Clausen and P. Schneeweiss, Phys. Rev. A **92**, 043819 (2015).

[2] *Quantum state-controlled directional spontaneous emission of photons into a nanophotonic waveguide*, R. Mitsch *et al.*, Nature Comm. **5**, 5713 (2014).